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Development of Unstructured Grid Linkage Methodology and Software for CE-QUAL-ICM

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Development of Unstructured Grid Linkage Methodology and Software for CE-QUAL-ICM

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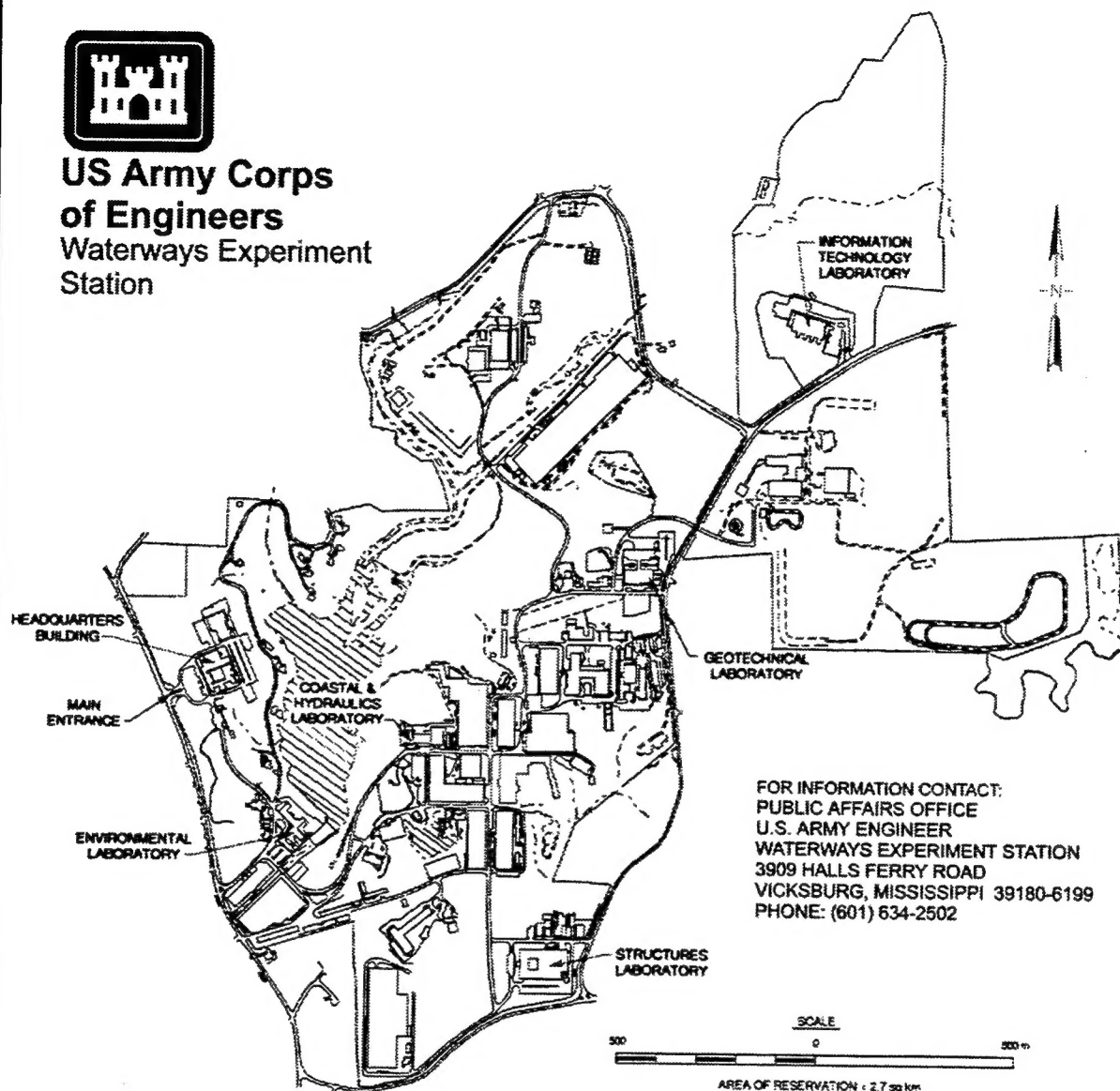
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Final report

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Preface

The work reported herein was conducted as part of the Water Quality Research Program (WQRP), Work Unit 32808, "Model of Contaminant Transport and Fate at Corps Projects." The WQRP is sponsored by the Headquarters, U.S. Army Corps of Engineers (HQUSACE), and is assigned to the U.S. Army Engineer Waterways Experiment Station (WES) under the purview of the Environmental Laboratory (EL). Funding was provided under Department of the Army Appropriation 96X3121, General Investigation. The WQRP is managed under the Environmental Modeling, Simulation, and Assessment Center (EMSAC), Dr. John W. Barko, Director for EL. Mr. Robert C. Gunkel was Assistant Manager for the WQRP. Program Monitor during this study was Mr. Frederick B. Juhle, HQUSACE.

The Principal Investigator of Work Unit 32808 was Dr. Mark S. Dortch, Chief, Water Quality and Contaminant Modeling Branch (WQCMB), Environmental Processes and Effects Division (EPED), EL. The work reported herein was conducted by Dr. Raymond S. Chapman, Ray Chapman and Associates, Vicksburg, MS, and Mr. Terry K. Gerald, AScl, Inc., Vicksburg, MS, under contract to WES. This report was prepared by Dr. Chapman and Mr. Gerald. Dr. Dortch monitored the contract and reviewed, edited, and revised the report.

This study was conducted under the general supervision of Dr. Richard E. Price, Acting Chief, EPED, and Dr. John Harrison, Director, EL. This report was reviewed by Messrs. Thomas Cole and Ross Hall, WQCMB.

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1 Introduction

Background

CE-QUAL-ICM (Cерco and Cole 1995) is a three-dimensional (3-D) water quality model based on the finite volume approach. There are two versions of this model, a eutrophication version documented by Cerco and Cole (1995), and a toxic substance version referred to as ICM/TOXI documented by Wang et al. (1996). The project that funded the development of ICM/TOXI also funded the present study reported herein.

Neither version of CE-QUAL-ICM (ICM) solves for hydrodynamics, so this information must be supplied by a hydrodynamic model for driving transport in the ICM model. The ICM model is usually linked to output from CH3D-WES (Johnson et al. 1991), a 3-D finite difference hydrodynamic model based on a structured grid scheme. Structured grids assume that computational cells are ordered along columns and rows, whereas unstructured grids allow cells to be arranged in a nonordered fashion. Thus, unstructured grids allow greater flexibility for describing the geometry of the domain.

RMA10 (Norton, King, and Orlob 1973; Thomas and McAnally 1990) is a 3-D finite element hydrodynamic model frequently used by the U.S. Army Engineer Waterways Experiment Station (WES). RMA10 is based on an unstructured grid approach. There was a need for developing a linkage to the RMA10 model to allow greater flexibility provided by unstructured grids for conducting water quality and contaminant model studies.

Objective and Scope

The objective of this study was to develop software to provide linkage of RMA10 output to the ICM code and to test the success of the linkage for simple test cases. The software development consisted of basically three parts: (a) development of a code (MAPPER) to map the finite element grid configuration and geometry information into a file that can be interpreted by the ICM code; (b) development of an RMA10 postprocessor code (FEMCONVT) to convert RMA10 velocity and water surface information at nodes to flows and

cell areas and volumes for each ICM cell; and (c) modifications within ICM to conform to the RMA10 linkage. Linkage testing consisted of checking local and global volume and mass conservation and examining the transport against known solutions. It is important to maintain mass conservation in water quality models since they are based on the mass conservation principle.

This report is organized into chapters on Introduction, Implementation, Testing, and Summary and Recommendations. Appendixes A-C deal with the MAPPER, FEMCONVT, and ICM codes.

2 Implementation

The basic requirements for the design and development of an unstructured grid linkage methodology for ICM are as follows: (a) generating a geometry file that relates the elements and their geometric attributes for an unstructured grid hydrodynamic model, such as RMA10, to flow faces and computational cells of ICM; (b) assigning a tagging system to relate flows from the hydrodynamic model to ICM flow faces; (c) establishing a convention for positive/negative flow directions; and (d) computing integrated flows across and normal to each hydrodynamic element face. The linkage program MAPPER conducts the first three tasks, while the linkage program FEMCONVT conducts the last.

MAPPER

The linkage geometry and map files are derived from the RMA10 element connection file that is generated for a hydrodynamic run. A C language program (MAPPER.C) was written to generate this information. MAPPER.C is described and listed in Appendix A. Descriptions of the RMA10 node and element connectivity scheme were obtained from the RMA10 documentation (Thomas and McAnally 1990; Brigham Young University 1994). The element connection file, generated by an RMA10 preprocessor code, which resides within the WES Coastal and Hydraulics Laboratory (CHL), provides element and node numbering, the 3-D coordinates of each node within the grid, and boundary designation information. This file is read by MAPPER.C, which generates the geometry (GEO) and map (MAP) files required as input to ICM.

To accommodate unstructured grid hydrodynamics, the GEO file was modified so that a one-dimensional array of centroid-based grid distances, which are direction sensitive, is computed and replaces the original box lengths (i.e., $BL(IB(F), QD(F))$). The centroid-based grid lengths data consist of (a) distance from centroid of IB cell to flow face (BID); (b) centroid to centroid distance between IB and JB cells (BI); (c) centroid to centroid distance between the ILB cell and IB (BIL); and (d) centroid to centroid distance between the JB cell and JRB cell (BIR) (see Figure 1). The specification of the ILB, IB, JB, and JRB ICM cell numbers (Figure 1) is accomplished through examination of the element connection file. Specifically, when elements that share common mid-side nodes are identified, a cell face between boxes IB and JB is defined. Cells

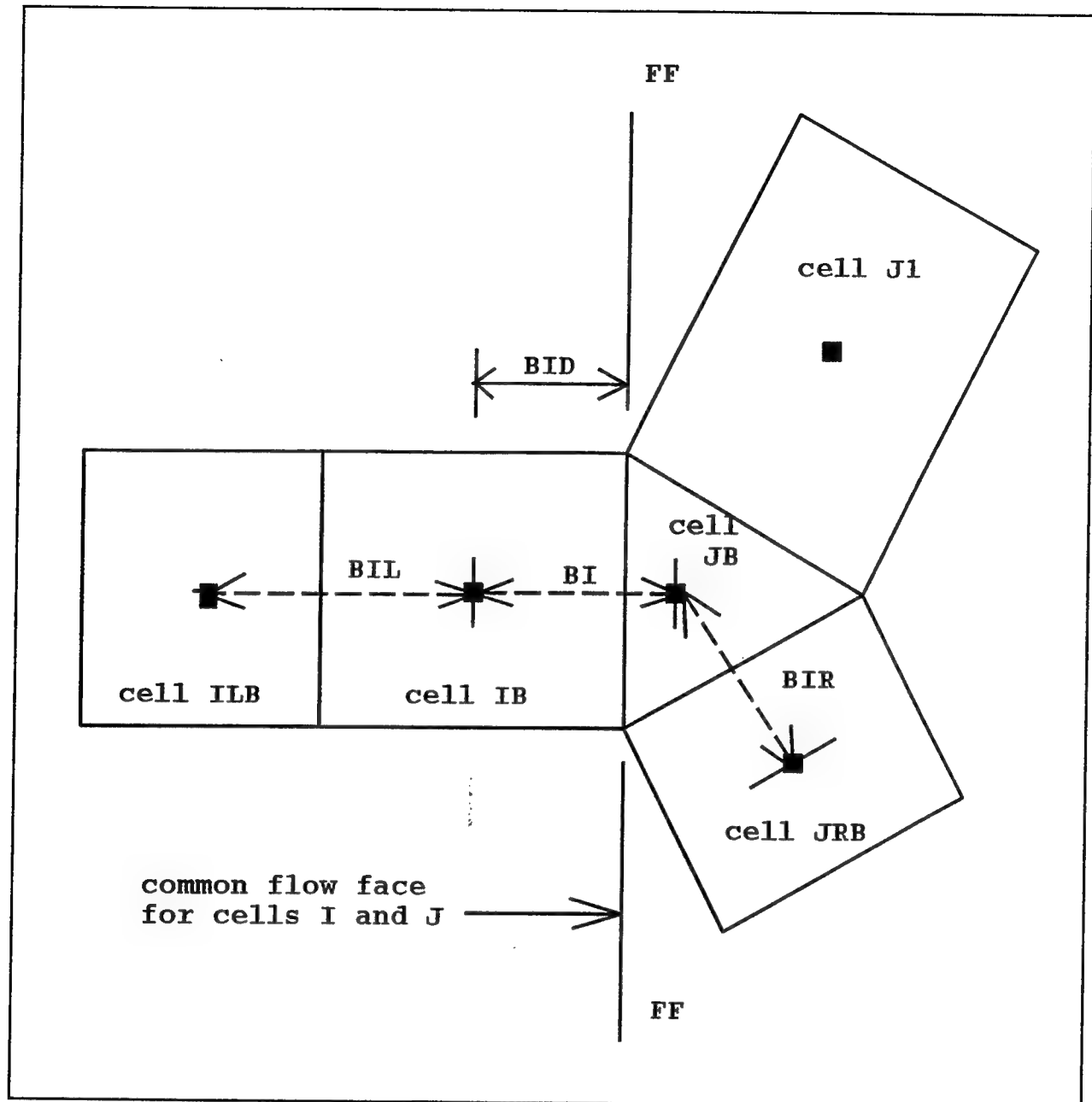


Figure 1. Grid nomenclature

to the right or left of cells with a common flow face are determined by selecting the cell with the shortest centroid distance. For example, as shown in Figure 1, the centroid distance from Cells JB to JRB is shorter than the distance from Cells JB to J1; thus, Cell JRB is selected as the adjacent right cell, or the far downstream cell for the QUICKEST weighting, and BIR is the distance from JB to JRB.

Due to the fact that unstructured grids have no preferred grid direction, a convention has been adopted. A flow direction for the establishment of the GEO

and MAP files is assumed based upon the cell numbering scheme obtained from RMA10. In the horizontal direction, flow is defined to be positive when it passes from a smaller RMA10 element number to a larger RMA10 element number. In the vertical direction, flows are defined positive upward, which is the convention used in both RMA10 and ICM. When the flow field is read in from the HYD file, the actual flow directions relative to the assumed flow directions are determined so that the proper cells are sampled for the QUICKEST advection operators.

The general concept of the MAP file was unaltered; however, additional information was required to relate the RMA10 and ICM grids. The processor program MAPPER assigns ICM cell numbers to RMA10 element numbers and writes the ordered pairs as the first set of records in the MAP file. The correspondence between hydrodynamic elements and ICM cells is arbitrary in that the connection is accomplished via flow face definitions. This approach is adopted so that the existing convention for numbering cells and flow faces in ICM is unaltered.

The RMA10 element edges and ICM flow faces are related in the MAP file via a tag. In the horizontal direction, the flow faces between adjacent cells in ICM are tagged to mid-side nodes in RMA10, which are defined along element edges. Vertical flow faces in ICM are tagged to the top of each element in RMA10. These tags are used via translation arrays to relate RMA10 flow locations to the corresponding sequentially numbered ICM flow face numbers.

Boundaries within the RMA10 grid are specified via nodal codes that define land, inflow, and tidal or head boundaries. These codes are used in MAPPER to specify boundaries in the MAP file.

FEMCONVT

The Fortran language program FEMCONVT.f was written by Dr. R. C. Berger of the WES CHL to read a binary RMA10 hydrodynamic output file and convert nodal velocities and surface elevations into cell face areas (including planar surface areas), volumes, and flows, which are written to another output file (HYD file). A listing of FEMCONVT is provided in Appendix B. The output of FEMCONVT is segregated into horizontal and vertical components. In the horizontal direction, the information provided is time-varying horizontal flow face areas and flows for each mid-side node. The vertical part of the hydrodynamic output provides element number, element planar surface area, volume, and the vertical flow defined on the top face of each element.

ICM Modifications

The original advection operator in ICM was designed to work with structured grid hydrodynamic models such as CH3D-WES (Chapman 1988). As a result, the grid is described by rows and columns of grid cells and box lengths. These

box lengths are used to compute the QUICKEST multipliers used for transport. Due to the success realized during numerous applications of the QUICKEST transport algorithm in both the ICM and CE-QUAL-W2 models (Dortch, Chapman, and Abt 1991; Chapman 1992; Chapman and Cole 1992), a similar approach was adopted for the unstructured version of ICM. The unstructured grid modifications made to the original version of ICM are presented in Appendix C. For ICM to accommodate unstructured hydrodynamic models such as RMA10, the QUICKEST multipliers had to be recast in terms of element centroid to centroid distances. As previously discussed, the linkage processor program MAPPER generates the four length scales needed to develop the QUICKEST multipliers. Using these length scales, the QUICKEST multipliers were rewritten and checked to ensure that the advection multipliers summed to one, and the diffusive multipliers summed to zero.

Linkage Procedure

To complete a linkage of RMA10 and ICM, the steps outlined below must be completed.

- a. A binary output file generated by RMA10, which contains the time-invariant grid and time-varying hydrodynamic data, must be obtained from the hydrodynamic modeling team. The name of this file is specified as RMA10 input, so it is arbitrary.
- b. With regard to the time-invariant grid data, a program named R4ICR10.f, written and provided by CHL, is used to read the RMA10 binary file and generate a 3-D ASCII element connection file named R4ICR10.out. This file describes the juxtaposition of all elements and nodes in the RMA10 grid.
- c. The linkage program MAPPER.C reads R4ICR10.out and generates the ICM MAP and GEO files. The number and position of ICM cells or boxes are determined by MAPPER automatically. Presently, a parameter statement within the MAPPER code defines "number_of_layers," which must be set to the desired number of layers. This parameter can be used to limit the output to a single layer for debug purposes. When this parameter is set to the correct number of RMA10 layers, the complete MAP and GEO files are automatically generated. MAPPER input (i.e., R4ICR10.out) and output files for a simple 3 by 2 by 2 grid are presented in Appendix D.
- d. The time-varying hydrodynamic data are also extracted from the same RMA10 binary output file. This is accomplished using the FEMCONVT.f program. This program has one interactive input, which is the RMA10 binary file name. All grid parameters are read from the RMA10 binary file. The output of this program is an ASCII ICM HYD file. At this time, FEMCONVT.f has several limitations:

- ASCII output should be written in binary to reduce space requirements for applications with large output files.
 - Base elevation in feet relative to an RMA10 datum must be hardwired.
 - FEMCONVT only works for quadrilateral elements.
 - Parameter statements must be checked to ensure the code will accommodate the size of the grid.
 - Vertical diffusivities required by ICM are not computed nor output.
 - There is no provision for temporal or spatial averaging of hydrodynamic output.
- e.* Two additional parameters must be defined in the ICM file WQM_COM.INC. NFEMHFFP and NFEMVFFP are the maximum number of horizontal and vertical flow faces, respectively.

3 Testing

Volume Balance Testing

Initial testing of the linkage methodology using hydrodynamic flow information was performed on a simple 26 by 4 by 3 rectangular contracted channel comprised of quadrilaterals as shown in Figure 2. To test both local and global volume conservation, a single steady-state flow field was used. Given that the flow field has in fact converged to a steady-state solution, successive applications of the flow field using the steady-state distribution of element volumes as an initial state should result in no temporal change in volume. Using these data, ICM was run using a 1-hr hydrodynamic update for 0.2 days, or two hydrodynamic updates. As expected, global volume conservation was achieved. However, significant variations in local volume conservation were observed throughout the grid. This problem was further investigated by performing flow balances on individual cells. In regions where elements were orthogonal, flow imbalances on the order of 1 percent were found, where the error in flow balance is based on the difference in the sum of the flows scaled by the maximum flow in or out of that cell. In regions where elements were nonorthogonal, flow imbalances were on the order of 60 percent. Discussions with CHL suggested that this problem can be overcome or at least reduced to errors on the order of a few percent. Means of correcting the flow/volume imbalances are being pursued.

Given that RMA10 flow fields can be produced with small but possibly acceptable volume errors, two alternatives can be adopted that will result in a local volume balance. The simplest option is to use the flows from the RMA10 hydrodynamic processor, but not use the resulting volumes. Under this scenario, time-varying volumes are computed within ICM using the previously computed volume and the input flows, thereby ensuring volume and mass conservation. The downside of this option is that if a persistent net loss or gain is realized in one or more cells, problems could develop during long-term simulations. Specifically, cells could either dry out or become unrealistically large.

Alternatively, both RMA10 flows and volumes can be used by ICM. The RMA10 flow data would again be used within ICM to calculate conserving volumes for each hydrodynamic update interval. The difference in the RMA10 volumes and ICM volumes can then be used to determine the volume errors for

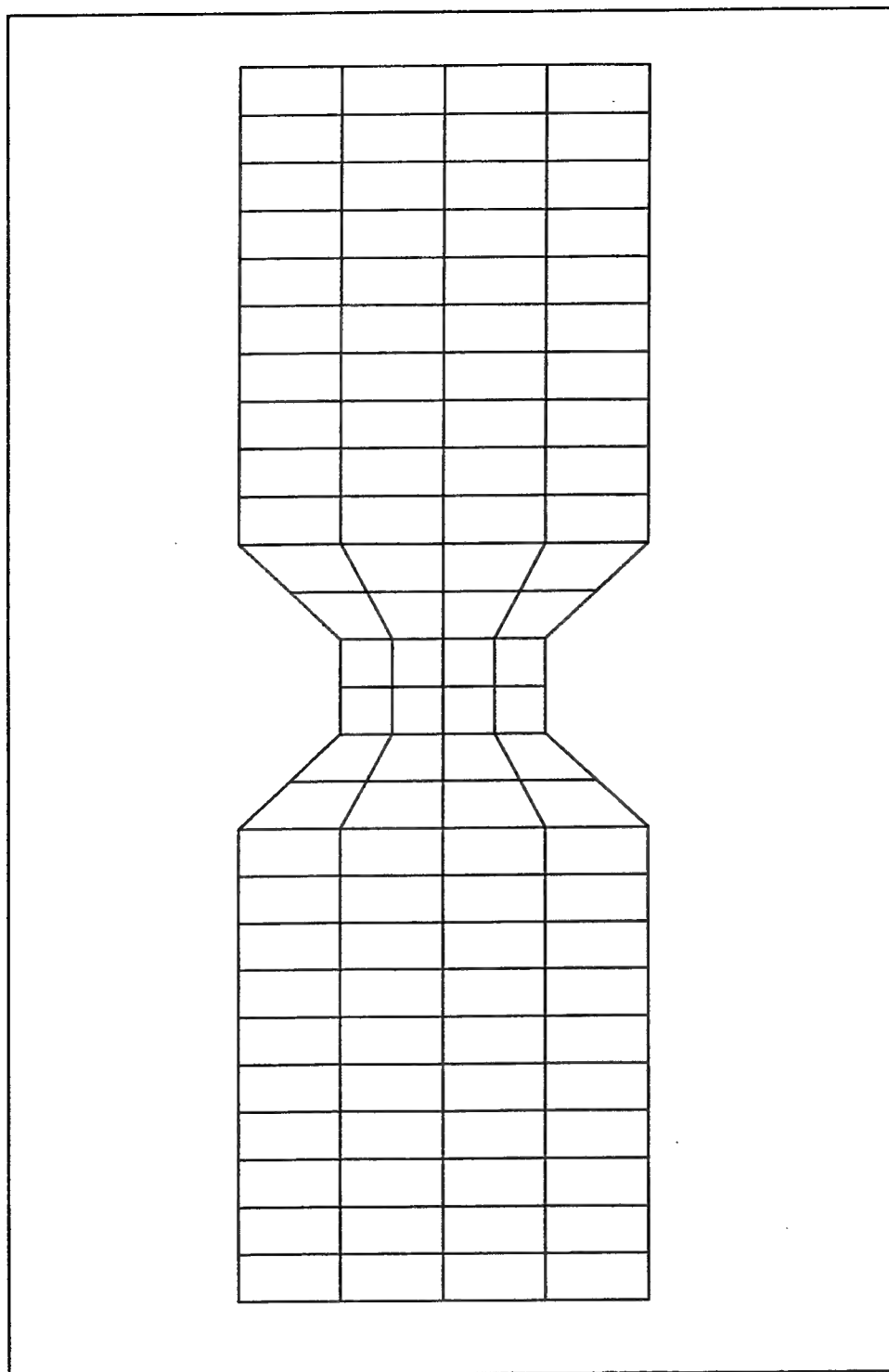


Figure 2. Volume balance test grid

each cell. If the volume error is ignored, i.e., RMA10 volumes are used, the model will not conserve mass, but concentrations will be conserved. For example, if a water quality constituent of 10 ppm is introduced into a bay that

contains 10 ppm, the concentrations will all remain 10 ppm, but some mass of the constituent will be gained or lost.

Volume and mass conservation can be forced when using both RMA10 flows and volumes by introducing a volume error correction. However, under this option the concentrations will not remain conservative, or 10 ppm everywhere as in the previous example. The error correction for each hydrodynamic update interval is computed and added (or subtracted) incrementally over the ICM time-steps within that update interval. Thus, the ICM volume computed at the end of each hydrodynamic update interval will be identical to the corresponding RMA10 volume. The simplest way to implement this correction is to generate a source flow by dividing the total volume error for each hydrodynamic update interval by the hydrodynamic update time interval. As the ICM simulation proceeds, a volume source/sink can be added/subtracted by multiplying the source flow by the ICM time-step.

Transport Testing

To test the revisions to ICM for the unstructured grid QUICKEST multipliers, transport testing was done using a one-dimensional rectangular grid set up without and with the unstructured grid multipliers as derived from the GEO and MAP files generated by MAPPER. The RMA10 model was not used for these tests. This grid consisted of 25 boxes 100 m in length with 1-m² cell face areas. A constant flow rate of 0.1 m³/sec was specified with no horizontal diffusion. Specifying a constant source concentration at the inflow, the predicted square wave concentrations in both simulations (i.e., with structured and with unstructured grid) were identical as shown in Figures 3 and 4. The algorithm was tested for variable grid spacing by alternating between 100- and 50-m box lengths and repeating the simulations. Additionally, both positive and negative flows were tested. All runs yielded identical results, which confirmed correct implementation of QUICKEST.

Additional testing of transport was performed using a steady-state RMA10 hydrodynamic flow field. A rectangular channel RMA10 grid was used consisting of 10 elements along the channel, 4 elements across the channel, and 3 elements deep (see Figure 5). Output from RMA10 was used to drive ICM. Exact global mass conservation was verified via a simulation of a conservative tracer spot dump and simulation of a uniform tracer concentration throughout the grid and boundaries. In addition, a constant source square wave test was performed. Despite the coarseness of the grid, the expected characteristics of QUICKEST are preserved in that minimal undershoot and overshoot and smearing of the wave occur over about five grid points (see Figure 6).

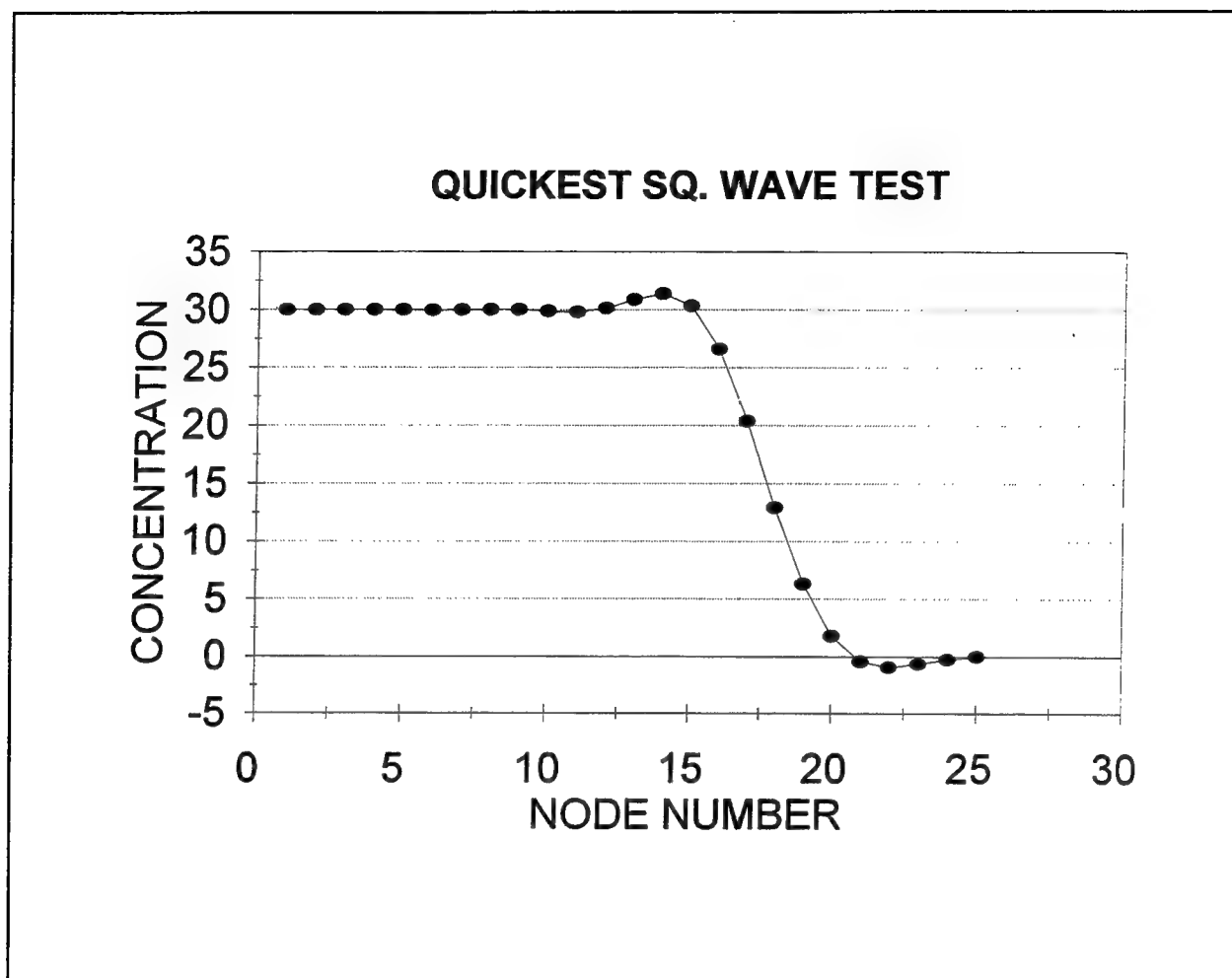


Figure 3. Square wave test result with structured grid QUICKEST multipliers

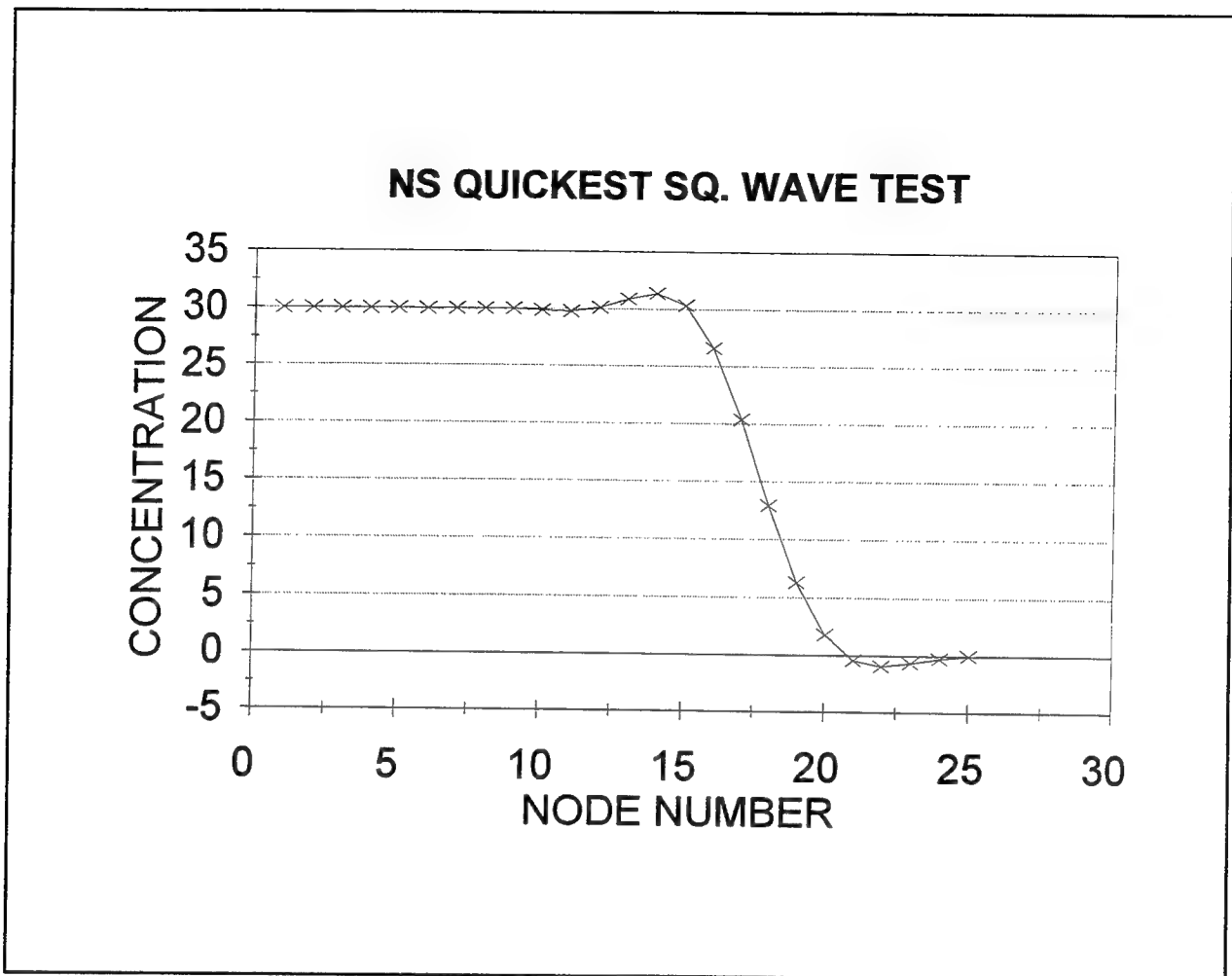


Figure 4. Square wave test result with unstructured grid QUICKEST multipliers

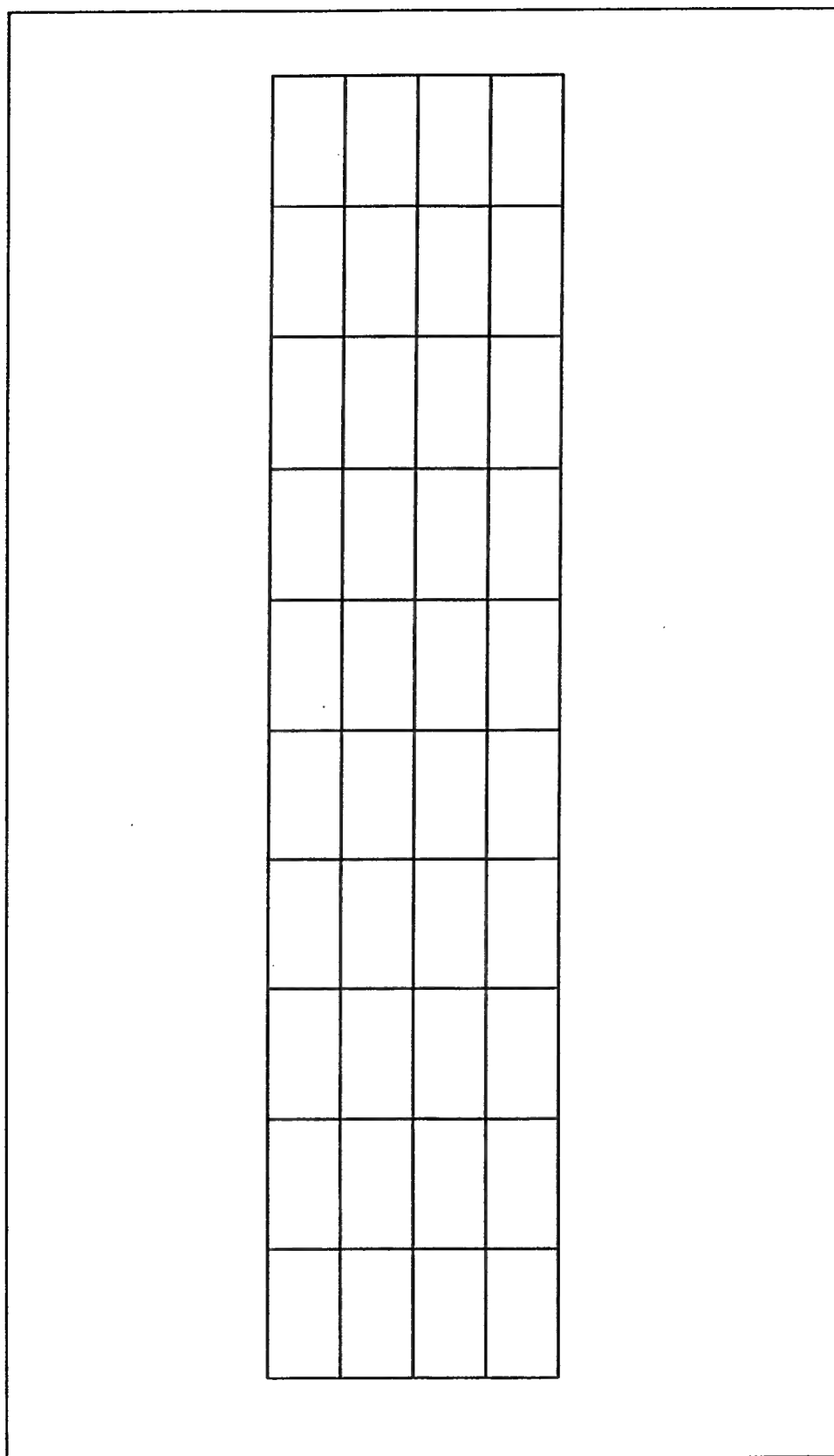


Figure 5. Transport test grid

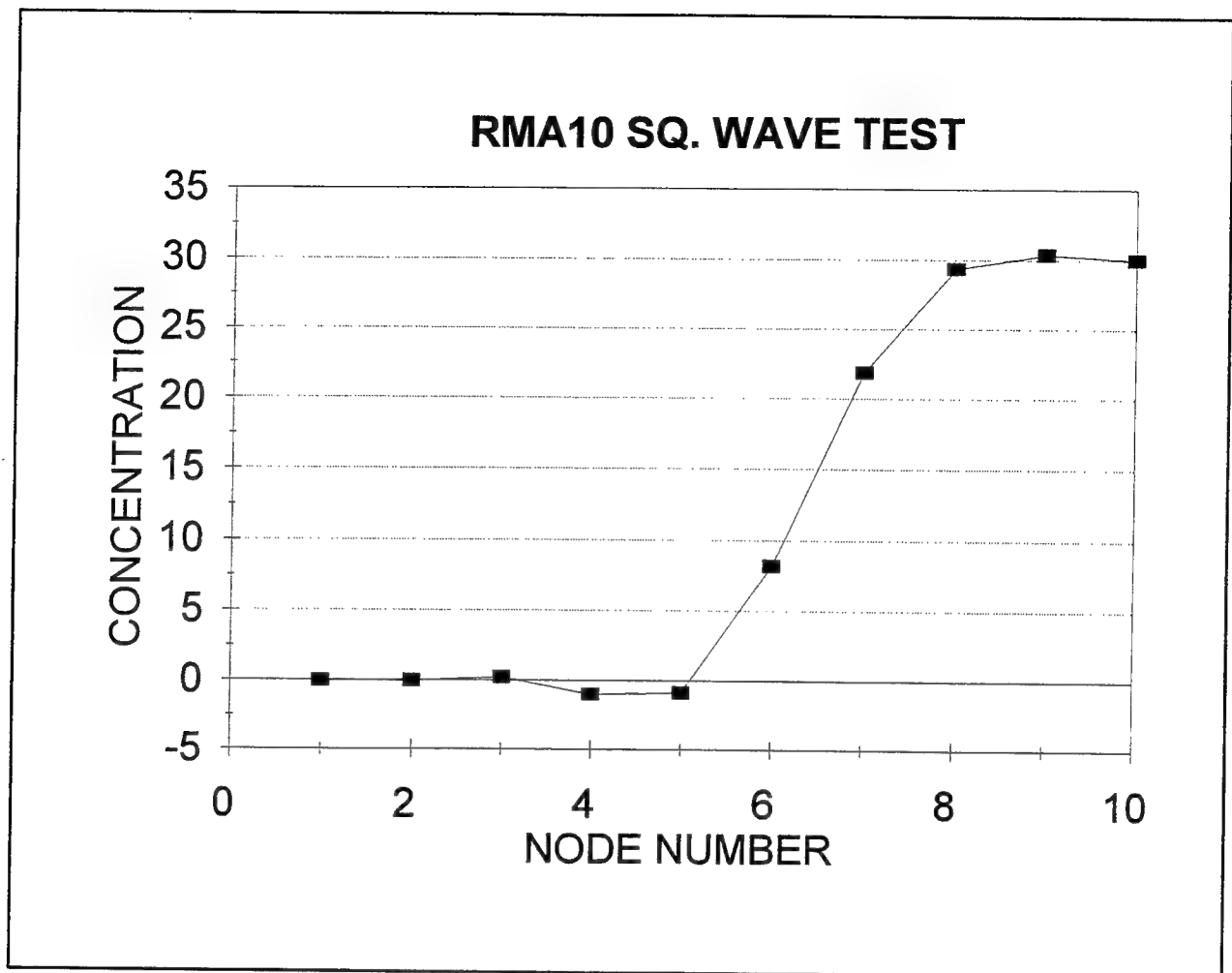


Figure 6. Square wave test result for RMA10-ICM transport test

4 Summary and Recommendations

A linkage methodology has been developed, implemented, and tested that allows CE-QUAL-ICM to use unstructured grid hydrodynamic information from the RMA10 finite element model. This has been accomplished through the development of two postprocessor programs, which provide flow and linkage information to ICM. Initial testing of volume conservation suggests that local volume conservation problems inherent within RMA10 limit the general skill of the linkage system; however, a procedure for correcting the volume errors within ICM is outlined. Irrespective, results of the present study suggest that further work towards eliminating volume conservation errors within RMA10 is warranted. In addition, a centroid-based QUICKEST advection scheme consistent with the unstructured form of RMA10 has been developed, implemented, and tested. Testing of the scheme shows that it is mass conservative and that it provides results consistent with the well-tested structured grid version of QUICKEST previously employed in ICM.

With respect to future refinements of the linkage methodology, in addition to either correcting for or eliminating the local volume conservation errors obtained from RMA10, the hydrodynamic processor FEMCONVT needs to be generalized to accommodate combinations of triangular and quadrilateral elements. Furthermore, additional work is required to integrate vertical eddy diffusivities within RMA10 so that cell face values can be provided to ICM. Subsequent to these and other more minor improvements outlined in Chapter 2, the complete linkage methodology should be tested using a real time-varying field application.

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Appendix A

MAPPER Description and Source Code Listing

The following is a brief description of the internal steps followed by the program MAPPER.C that generates the MAP and GEO files needed by the ICM model. This program is run after the RMA10 program is executed. There is a program called R4ICR10.F written by the U.S. Army Engineer Waterways Experiment Station Coastal and Hydraulics Laboratory that extracts the two files used as input by MAPPER.C from the RMA10 binary output file. A listing of the MAPPER.C source code follows the description.

The step by step operations of MAPPER.C are listed below.

Read the node-to-element connection table. Allocates each "Element" as a column and assigns an ID.

Subroutine call: readElementConnectionFile()

Subroutine description: The routine opens and reads the element to node connection table file. This file provides information that uniquely relates an element or column identification number to the associated nodes. Additional information obtained from this file is the coordinates of each node. At this point, it is assumed that RMA10 node identification numbers are being used. This routine creates a unique "arc" for each side of the surface layer elements, which can be either trapezoidal or triangular.

Source of input file: Input file is generated by R4ICR10.f.

Read boundary information.

Subroutine call: readBoundaryArcFile()

Subroutine description: Routine reads a file that contains information about all "special" nodes in the RMA10 grid. These special nodes are nodes at which some physical parameters are specified such as head values, wall boundaries, open boundaries, interior boundaries, etc. This information, in addition to the node data from Step 1, completely describes the RMA10 grid structure.

Source of input file: Input file is generated by R4ICR10.f.

Relate each arc to the adjacent columns.

Subroutine call: mapColumnsToArcs()

Subroutine description: Routine determines the adjacent column identification numbers for each arc.

Relate each column to its neighbors.

Subroutine call: mapNeighborColumnsForEachColumn()

Subroutine description: Routine determines for each column, all the columns that share a common arc. Thus, a list is generated for each column that contains all of its neighbor columns.

Determine arc type.

Subroutine call: determineArcTypeF()

Subroutine description: Routine examines each arc and determines its type, which is defined to be (a) INTERNAL - arc that is internal to the grid, (b) BOUNDARY - arc lies at an open boundary, and (c) WALL - arc lies at the wall of the grid. The arc type is defined using the nodal boundary data.

Determine upstream and downstream columns.

Subroutine call: mapUpstreamAndDownstreamColumnsForEachColumnF()

Subroutine description: Routine defines adjacent columns.

Create a list of all elements in the 3-D grid.

Subroutine call: createElementList()

Subroutine description: Routine will generate a list of all elements in the RMA10 grid. First, it generates surface layer or column elements. Next, for

each column, it will define elements within that column from the surface down. The order of elements is that defined by RMA10.

Map neighboring elements.

Subroutine call: `mapElementToNeighborElements()`

Subroutine description: Routine determines neighboring elements. This is accomplished by using the column information previously defined.

Check for internal and boundary flow faces.

Subroutine call: `generateHorizontalFlowFaceListF()`

Subroutine description: Routine examines each arc, its type. If the type is "INTERNAL" or "BOUNDARY," it will create a flow-face for that arc; this is done in layer order starting at the surface then going down. For each defined flow face, the adjacent elements of that flow face are listed.

Determine far upstream elements for each horizontal flow face.

Subroutine call: `mapHorizontalFlowFaces()`

Subroutine description: Routine determines for each flow face its far upstream and far downstream element IDs using the adjacent element ID information.

Create the vertical flow face list.

Subroutine call: `mapVerticalFlowFaces()`

Subroutine description: Routine uses the column information defined above and creates a vertical flow face between each element. It also does the vertical mapping of upstream and downstream elements.

Define tags that relate RMA10 and ICM flow faces.

Subroutine call: `setFlowFaceIdentifierTags()`

Subroutine description: Routine examines each flow face and tags it with a unique identifier. This unique identifier is defined as (a) horizontally oriented flow face (the top center node ID of each flow face); and (b) vertically oriented flow face (the RMA10 element ID of the element below the flow face).

Number ICM flow faces.

Subroutine call: `renumberAllFlowFacesForOutputF()`

Subroutine description: Routine rennumbers the flow face identifications consistent with the ICM convention.

Calculate surface areas and the centroid locations.

Subroutine call: `calculateColumnSurfaceAreaAndCentroid()`

Subroutine description: Routine will calculate surface area and centroid location using the surface node coordinates.

Calculate required distances between centroids.

Subroutine call: `calculateDistanceBetweenCentroidsF()`

Subroutine description: Routine calculates the following length scale information for each flow face:

- (a) BIL = Distance between far upstream element centroid and upstream element centroid.
- (b) BI = Distance between upstream element centroid and the downstream element centroid.
- (c) BIR = Distance between downstream element centroid and far downstream element centroid.
- (d) BID = Distance between flow face and the upstream element centroid.

Print "MAP FILE".

Subroutine call: `printFlowFaceListF()`

Subroutine description: Routine writes "MAP" file data.

Print "GEO FILE".

Subroutine call: `printGeoFileF()`

Subroutine description: Routine writes "GEO" file data.

```

/* PROGRAM NAME: MAPPER.c

PROGRAMMER: Terry K. Gerald

PURPOSE: Build the "MAP" file and the "GEO" file for ICM from an RMA10
         finite element model grid.

*/

#include <stdio.h>
#include <string.h>
#include <math.h>

#define TRUE      1
#define FALSE     0

#define YES       1
#define NO        0

#define OK        1

#define SET       1
#define NOT_SET   2

#define GE        10
#define GNN       20
#define OTHERSTUFF 30

#define TRAPAZOID 100
#define TRIANGLE  200

#define NUMBER_OF_LAYERS 3

```

```

#define MAXARGS      20

#define INTERNAL     70
#define BOUNDARY     80
#define WALL         90

#define VERTICAL     100
#define HORIZONTAL   200
#define INBETWEEN    300

/* _____ */

typedef struct ELEMENT_BLOCK_STRUCT
{
    struct ELEMENT_BLOCK_STRUCT *pLastElementBlockPtr;
    struct ELEMENT_BLOCK_STRUCT *pNextElementBlockPtr;
    int elementId;
    int rma10ElementId;
    int columnId;
    int elementType;
    int arcCount;
    int layerId;
    int faceId[6];
    int commonNeighborElementId[4];
    int commonNeighbor2ElementId[4];

    int bottomFlowFaceId;
    struct ELEMENT_BLOCK_STRUCT *elementAbovePtr;
    struct ELEMENT_BLOCK_STRUCT *elementBelowPtr;
} ELEMENT_BLOCK;

```

```

typedef    ELEMENT_BLOCK *PELEMENT_BLOCK;

ELEMENT_BLOCK    *pHeadElementListBlockPtr;

int    globalElementCount = 0;

PELEMENT_BLOCK    *lookupElementPtrArray = NULL;

typedef struct COLUMN_BLOCK_STRUCT
{
    struct COLUMN_BLOCK_STRUCT    *pLastColumnBlockPtr;
    struct COLUMN_BLOCK_STRUCT    *pNextColumnBlockPtr;
    int    columnId;
    int    columnType;
    int    arcCount;
    int    numberOfLayers;
    int    arcIds[4];
    int    commonNeighborColumnCount;
    int    commonNeighborColumnId[4];
    int    commonNeighborArcId[4];
    int    commonNeighbor2ColumnId[4];

    float    surfaceArea;
    float    centroidX, centroidY;

    PELEMENT_BLOCK    elementPtr;
    PELEMENT_BLOCK    surfaceElementPtr;
} COLUMN_BLOCK;

typedef    COLUMN_BLOCK *PCOLUMN_BLOCK;

COLUMN_BLOCK    *pHeadColumnListBlockPtr;

```



```

int      globalColumnCount = 0;

PCOLUMN_BLOCK  *lookupColumnPtrArray = NULL;

typedef struct NODE_BLOCK_STRUCT
{ struct NODE_BLOCK_STRUCT *lastNodeBlockPtr;
  struct NODE_BLOCK_STRUCT *nextNodeBlockPtr;
  int nodeId;
  float coordinates[3];
} NODE_BLOCK;

typedef NODE_BLOCK *PNODE_BLOCK;

PNODE_BLOCK  pHeadNodeBlockPtr = NULL;

int      globalNodeCount = 0;

PNODE_BLOCK  *lookupNodePtrArray = NULL;

typedef struct ARC_BLOCK_STRUCT
{ struct ARC_BLOCK_STRUCT *pLastArcBlockPtr;
  struct ARC_BLOCK_STRUCT *pNextArcBlockPtr;
  int arcId;
  int nodeId[3];
  int adjacentColumn[2];
  int type;
} ARC_BLOCK;

typedef ARC_BLOCK *PARC_BLOCK;

PARC_BLOCK  pHeadArcListBlockPtr = NULL;

```

```

int      globalArcCount = 0;

typedef struct FLOWFACE_BLOCK_STRUCT
{ struct FLOWFACE_BLOCK_STRUCT *pLastFlowFaceBlockPtr;
  struct FLOWFACE_BLOCK_STRUCT *pNextFlowFaceBlockPtr;
  struct ARC_BLOCK_STRUCT *arcPtr;
  int  identifierTag;
  int  arcId;
  int  flowFaceId;
  int  modelFlowFaceId;
  int  layerId;
  int  farDownstreamElementId;
  int  downstreamElementId;
  int  upstreamElementId;
  int  farUpstreamElementId;
  int  type;
  int  orientation;
  int  adjacentColumn[2];
  int  adjacentElement[2];
  float distanceBetweenCentroids;
  float upstreamDistanceBetweenCentroidAndFace;
  float downstreamDistanceBetweenCentroidAndFace;
  float distanceBetweenUpstreamCentroids;
  float distanceBetweenDownstreamCentroids;
} FLOWFACE_BLOCK;

typedef FLOWFACE_BLOCK *PFLOWFACE_BLOCK;

PFLOWFACE_BLOCK  pHeadFlowFaceListBlockPtr = NULL;
PFLOWFACE_BLOCK  pHeadSurfaceFlowFaceListBlockPtr = NULL;
PFLOWFACE_BLOCK  pTailSurfaceFlowFaceListBlockPtr = NULL;

```

```

int      globalFlowFaceCount = 0;

PFLOWFACE_BLOCK   *lookupFlowFacePtrArray = NULL;

typedef struct BOUNDARY_NODE_BLOCK_STRUCT
{ struct BOUNDARY_NODE_BLOCK_STRUCT *lastBoundaryNodeBlockPtr;
  struct BOUNDARY_NODE_BLOCK_STRUCT *nextBoundaryNodeBlockPtr;
  int boundaryNodeId;
} BOUNDARY_NODE_BLOCK;

typedef BOUNDARY_NODE_BLOCK *PBOUNDARY_NODE_BLOCK;

PBOUNDARY_NODE_BLOCK   pHeadBoundaryNodeBlockPtr = NULL;

/* int      globalBoundaryNodeCount = 0; */

typedef struct SURFACE_NODE_LIST_STRUCT
{
  int ndep;
  int nref;
} SURFACE_NODE_LIST;

typedef SURFACE_NODE_LIST *PSURFACE_NODE_LIST;

PSURFACE_NODE_LIST   surfaceNodeList;

/* _____ */
/* function prototypes */
/*

```

```

NODE_BLOCK
*allocateNewNodeBlockF();

-
BOUNDARY_NODE_BLOCK
*allocateNewBoundaryNodeBlockF();

ARC_BLOCK
*allocateNewSegmentArcBlockF();

ELEMENT_BLOCK
*allocateNewElementBlockF();

COLUMN_BLOCK
*allocateNewColumnBlockF();

FLOWFACE_BLOCK
*allocateNewFlowFaceBlockF();

PNODE_BLOCK
findNodePtrF(int);

PARC_BLOCK
findArcPtrF(int);

PCOLUMN_BLOCK
lookupColumnPtrF(int);

```

```

PELEMENT_BLOCK
lookupElementPtrF(int);

PFLOWFACE_BLOCK
lookupFlowFacePtrF(int);

int
iCheckIfCommonNodeInTwoArcsF(PARC_BLOCK, PARC_BLOCK);

void
readBoundaryArcFile();

int
getColumn(FILE *, char *, char *);

int
searchForNFIx(FILE *);

void
allocateNewElementByColumnBlockF( COLUMN_BLOCK *, int );

/* _____ */
/* _____ */
/* MAIN ROUTINE */
void main()

```

```

{
    readElementConnectionFile();

    /* Read the node-to-element connection
       table. Allocates each "Element" as
       a column. Column ID is also read in. */

    readBoundaryArcFile();

    /* Read from an RMA10 output file, which
       nodes are BOUNDARY nodes */

    /* Releate to each arc in a column, the
       two columns on each side */

    /* Releate each column to its neighbors */
    mapNeighborColumnsForEachColumn();

    /* Determine for each arc if it is an
       1) INTERNAL arc, 2) BOUNDARY arc or a
       3) WALL arc! */

    determineArcTypeFO();

    /* Map upstream and downstream columns */
    mapUpstreamAndDownstreamColumnsForEachColumnFO();

    createElementList();

    /* Create all elements */

    /* Map for each element its neighbor
       elements */
    mapElementToNeighborElements();

    /* Generate each horizontal flow-face
       utilizing the arc list */
}

```

```

generateHorizontalFlowFaceListF();

/* Determine relationship between the
   flow-face and it's adjacent elements */
mapHorizontalFlowFaces();

/* From the column lists generate the
   vertical flow-faces and determine
   their adjacent element ids */
mapVerticalFlowFaces();

/* Need to reference each flow-face
   with some type of information that
   RMA10 is aware of so the flow-faces
   can be ordered in way that preserves
   their geometric relationships to
   their elements . */
setFlowFaceIdentifierTags();

/* Renumber the flow-faces so that they
   are numbered increasing by layer
   instead of by column */
renumberAllFlowFacesForOutputF();

/* Calculate the geometry for each
   element */
calculateColumnSurfaceAreaAndCentroid();

calculateDistanceBetweenCentroidsF();

/* Print the "MAP" file */
printFlowFaceListF();

/* Print the "GEO" file */

```

```

printGeoFileF();
}

/* _____ */

NODE_BLOCK *allocateNewNodeBlockF()
{
    int i;
    NODE_BLOCK *aNodeBlock;

    static
    PNODE_BLOCK lastNodePtr;

    aNodeBlock = (PNODE_BLOCK)calloc(1,sizeof(NODE_BLOCK));

    aNodeBlock->lastNodeBlockPtr = NULL;
    aNodeBlock->nextNodeBlockPtr = NULL;

    aNodeBlock->nodeId = ++globalNodeCount;

    /* Set list ptrs */

    if(pHeadNodeBlockPtr == NULL)
    {
        pHeadNodeBlockPtr = aNodeBlock;
    }
}

```



```

else
{ lastNodePtr->nextNodeBlockPtr = aNodeBlock;
  aNodeBlock->lastNodeBlockPtr = lastNodePtr;
}'

lastNodePtr = aNodeBlock;

return(aNodeBlock);
}

/* _____ */

BOUNDARY_NODE_BLOCK *allocateNewBoundaryNodeBlockFQ()
{
int i;
BOUNDARY_NODE_BLOCK *aBoundaryNodeBlockPtr;

static
PBOUNDARY_NODE_BLOCK lastBoundaryNodePtr;

aBoundaryNodeBlockPtr = (PBOUNDARY_NODE_BLOCK)calloc(1,sizeof(BOUNDARY_NODE_BLOCK));

aBoundaryNodeBlockPtr->lastBoundaryNodeBlockPtr = NULL;
aBoundaryNodeBlockPtr->nextBoundaryNodeBlockPtr = NULL;

```

```

/* Set list ptrs */
if(pHeadBoundaryNodeBlockPtr == NULL)
{
    pHeadBoundaryNodeBlockPtr = aBoundaryNodeBlockPtr;
}
else
{
    lastBoundaryNodePtr->nextBoundaryNodeBlockPtr = aBoundaryNodeBlockPtr;
    aBoundaryNodeBlockPtr->lastBoundaryNodeBlockPtr = lastBoundaryNodePtr;
}

lastBoundaryNodePtr = aBoundaryNodeBlockPtr;

return(aBoundaryNodeBlockPtr);
}

/* _____ */

ARC_BLOCK *allocateNewArcBlock()
{
    int i;
    ARC_BLOCK *aArcBlock;

    static
    PARC_BLOCK lastArcPtr;

    aArcBlock = (PARC_BLOCK)calloc(1,sizeof(ARC_BLOCK));

    aArcBlock->pLastArcBlockPtr = NULL;
    aArcBlock->pNextArcBlockPtr = NULL;

```

```

aArcBlock->arcId = ++globalArcCount;

aArcBlock->adjacentColumn[0] = -1;
aArcBlock->adjacentColumn[1] = -1;

/* Set list ptrs */

if(pHeadArcListBlockPtr == NULL)
{ pHeadArcListBlockPtr = aArcBlock;
}
else
{ lastArcPtr->pNextArcBlockPtr = aArcBlock;
  aArcBlock->pLastArcBlockPtr = lastArcPtr;
}

lastArcPtr = aArcBlock;

return(aArcBlock);
}

/* _____ */

ELEMENT_BLOCK *allocateNewElementBlockF()
{
  int i;
  ELEMENT_BLOCK *anElementBlockPtr;

  static
  ELEMENT_BLOCK *lastElementPtr;

```

```

anElementBlockPtr = (PELEMENT_BLOCK)calloc(1, sizeof(ELEMENT_BLOCK));

anElementBlockPtr->pLastElementBlockPtr = NULL;
anElementBlockPtr->pNextElementBlockPtr = NULL;

anElementBlockPtr->elementAbovePtr=NULL;
anElementBlockPtr->elementBelowPtr=NULL;

for(i=0; i<6; i++)
    anElementBlockPtr->faceId[i] = -1;

globalElementCount++;

anElementBlockPtr->elementId= globalElementCount;

/* Set list ptrs */

if(pHeadElementListBlockPtr == NULL)
{
    pHeadElementListBlockPtr = anElementBlockPtr;
    lastElementPtr = anElementBlockPtr;
}
else
{
    lastElementPtr->pNextElementBlockPtr = anElementBlockPtr;
    anElementBlockPtr->pLastElementBlockPtr = lastElementPtr;
    lastElementPtr = anElementBlockPtr;
}

return(anElementBlockPtr);
}

```

```

/* _____ */

COLUMN_BLOCK *allocateNewColumnBlockF()
{
    int i;
    COLUMN_BLOCK *aColumnBlockPtr;

    static
    PCOLUMN_BLOCK lastColumnPtr;

    aColumnBlockPtr = (PCOLUMN_BLOCK)calloc(1, sizeof(COLUMN_BLOCK));

    aColumnBlockPtr->pLastColumnBlockPtr = NULL;
    aColumnBlockPtr->pNextColumnBlockPtr = NULL;

    aColumnBlockPtr->columnId = ++globalColumnCount;

    aColumnBlockPtr->commonNeighborColumnCount = 0;

    for(i=0; i<4; i++)
    {
        aColumnBlockPtr->commonNeighborColumnId[i] = -1;
        aColumnBlockPtr->commonNeighborArcId[i] = -1;
        aColumnBlockPtr->commonNeighbor2ColumnId[i] = -1;
    }

    /* Set list ptrs */
}

```

```

if(pHeadColumnListBlockPtr == NULL)
{ pHeadColumnListBlockPtr = aColumnBlockPtr;
}
else
{ lastColumnPtr->pNextColumnBlockPtr = aColumnBlockPtr;
aColumnBlockPtr->pLastColumnBlockPtr = lastColumnPtr;
}

lastColumnPtr = aColumnBlockPtr;

return(aColumnBlockPtr);
}

/* _____ */

FLOWFACE_BLOCK *allocateNewFlowFaceBlockF()
{
int i;
FLOWFACE_BLOCK *aFlowFaceBlockPtr;

static
PFLOWFACE_BLOCK lastFlowFacePtr;

aFlowFaceBlockPtr = (PFLOWFACE_BLOCK)calloc(1,sizeof(FLOWFACE_BLOCK));

aFlowFaceBlockPtr->pLastFlowFaceBlockPtr = NULL;
aFlowFaceBlockPtr->pNextFlowFaceBlockPtr = NULL;
aFlowFaceBlockPtr->arcPtr = NULL;

```

```

aFlowFaceBlockPtr->flowFaceId = ++globalFlowFaceCount;

aFlowFaceBlockPtr->adjacentColumn[0] = -1;
aFlowFaceBlockPtr->adjacentColumn[1] = -1;

aFlowFaceBlockPtr->adjacentElement[0] = -1;
aFlowFaceBlockPtr->adjacentElement[1] = -1;

/* Set list ptrs */

if(pHeadFlowFaceListBlockPtr == NULL)
{ pHeadFlowFaceListBlockPtr = aFlowFaceBlockPtr;
}
else
{ lastFlowFacePtr->pNextFlowFaceBlockPtr = aFlowFaceBlockPtr;
  aFlowFaceBlockPtr->pLastFlowFaceBlockPtr = lastFlowFacePtr;
}

lastFlowFacePtr = aFlowFaceBlockPtr;

return(aFlowFaceBlockPtr);
}

/* _____ */

void calculateCentroidOfGeneralizedTriangle(x,y,cList)
float x[3], y[3];
float *cList;

```

```

{
    float A, d, e;
    float x1,y1, x2,y2, x3,y3;
    float z1, z2, z3;

    /* First calculate arc midpoint
    locations */

    x1 = (x[1]+x[2]) / 2.0;
    y1 = (y[1]+y[2]) / 2.0;

    x2 = (x[2]+x[3]) / 2.0;
    y2 = (y[2]+y[3]) / 2.0;

    x3 = (x[3]+x[1]) / 2.0;
    y3 = (y[3]+y[1]) / 2.0;

    A = (x2*y3 - x3*y2) - (x1*y3 - x3*y1) + (x1*y2 - x2*y1);
    z1 = x1*x1 + y1*y1;
    z1 = x2*x2 + y2*y2;
    z1 = x3*x3 + y3*y3;

    d = (z1*y3 - z1*y2 - z2*y3 + z2*y1 + z3*y2 - z3*y1) / (-2.0*A);
    e = (-z1*x3 + z1*x2 + z2*x3 - z2*x1 - z3*x2 + z3*x1) / (-2.0*A);

    cList[0] = d; cList[1] = e;
}

/* _____ */

void calculateColumnSurfaceAreaAndCentroid()

```



```

{
    PCOLUMN_BLOCK columnPtr;
    PARC_BLOCK arcPtr;
    PNODE_BLOCK nodePtr;

    int arcId;
    int i, j, iTemp;
    int nodeIds[4];
    int nodeCount;
    float x[5], y[5];
    float area;
    int lastCornerNode;
    float centroidX, centroidY;
    float cList[2];

    int foundIt;

    int nodeIdList[13], nodeIdListCount;

    columnPtr = pHeadColumnListBlockPtr;

    while(columnPtr != NULL)
    {
        nodeCount = 0;

        /* Each column has 4 potential arcs */

        nodeIdListCount = 0;

        for(i=0; i<4; i++)

```

```

{
    if(columnPtr->arcIds[j] < 1) continue;
    arcId = columnPtr->arcIds[i];
    arcPtr = findArcPtrF(arcId);

    /* Check if arc already encountered */
    foundIt = NO;
    for(j=0; j<nodeIdListCount; j++)
        if( arcPtr->nodeId[0] == nodeIdList[j])
            foundIt = YES;

    if(foundIt == NO)
        nodeIdList[nodeIdListCount++] = arcPtr->nodeId[0];

    foundIt = NO;
    for(j=0; j<nodeIdListCount; j++)
        if( arcPtr->nodeId[2] == nodeIdList[j])
            foundIt = YES;

    if(foundIt == NO)
        nodeIdList[nodeIdListCount++] = arcPtr->nodeId[2];
}

nodeCount = nodeIdListCount;
for(i=0; i<nodeIdListCount; i++)
    nodeIds[i] = nodeIdList[i];

/* Now get coors of these nodes */
for(i=1; i<=nodeCount; i++)
    { nodePtr = findNodePtrF(nodeIds[i-1]);

```

```

x[i] = nodePtr->coordinates[0];
y[i] = nodePtr->coordinates[1];
}

/* Check if type of element */
switch(nodeCount)
{
case 3:
    area = 0.5*( x[1]*y[2] + x[2]*y[3] + x[3]*y[1]
                - y[1]*x[2] - y[2]*x[3] - y[3]*x[1] );
    calculateCentroidOfGeneralizedTriangle(x,y,cList);
    centroidX = cList[0];
    centroidY = cList[1];
    break;

case 4:
    area = 0.5*( x[1]*y[2] + x[2]*y[3] + x[3]*y[4] + x[4]*y[1]
                - y[1]*x[2] - y[2]*x[3] - y[3]*x[4] - y[4]*x[1] );
    centroidX = (x[1] + x[2] + x[3] + x[4])/4.0;
    centroidY = (y[2] + y[3] + y[4] + y[1])/4.0;
    break;
}

columnPtr->surfaceArea = area;

columnPtr->centroidX = centroidX;
columnPtr->centroidY = centroidY;

```

```

columnPtr = columnPtr->pNextColumnBlockPtr;
}
-
}
/* _____ */
float
calculate_BI_F(PFLOWFACE_BLOCK flowFacePtr)
{
    PELEMENT_BLOCK downstreamElementPtr, upstreamElementPtr;
    int    downstreamElementId, upstreamElementId;

    PCOLUMN_BLOCK  upstreamColumnPtr, downstreamColumnPtr;
    int    downstreamColumnId, upstreamColumnId;

    float    x,y, x1,y1, x2,y2;
    double   d2;
    float    d;

    upstreamElementId = flowFacePtr->upstreamElementId;
    upstreamElementPtr = lookupElementPtrF(upstreamElementId);
    if(upstreamElementPtr != NULL)
    {
        upstreamColumnId = upstreamElementPtr->columnId;
        upstreamColumnPtr = lookupColumnPtrF(upstreamColumnId);
    }

```

```

else
    upstreamColumnPtr = NULL;

    downstreamElementId = flowFacePtr->downstreamElementId;
    downstreamElementPtr = lookupElementPtrF(downstreamElementId);
    if(downstreamElementPtr != NULL)
    {
        downstreamColumnId = downstreamElementPtr->columnId;
        downstreamColumnPtr = lookupColumnPtrF(downstreamColumnId);
    }
    else
        downstreamColumnPtr = NULL;

    if( (upstreamColumnPtr != NULL) && (downstreamColumnPtr != NULL) )
    {
        x1 = upstreamColumnPtr->centroidX;
        y1 = upstreamColumnPtr->centroidY;

        x2 = downstreamColumnPtr->centroidX;
        y2 = downstreamColumnPtr->centroidY;

        d2 = (x1-x2)*(x1-x2) + (y1-y2)*(y1-y2);
        d2 = sqrt(d2);

        d = d2;
    }
    else
        d = 0.0;

    return(d);
}

```

```

/* _____ */

float
calculate_BID_F( PFLOWFACE_BLOCK flowFacePtr )
{
    PELEMENT_BLOCK downstreamElementPtr, upstreamElementPtr;
    int downstreamElementId, upstreamElementId;

    PELEMENT_BLOCK farDownstreamElementPtr, farUpstreamElementPtr;
    int farDownstreamElementId, farUpstreamElementId;

    PCOLUMN_BLOCK downstreamColumnPtr, upstreamColumnPtr;
    int downstreamColumnId, upstreamColumnId;

    PCOLUMN_BLOCK farDownstreamColumnPtr, farUpstreamColumnPtr;
    int farDownstreamColumnId, farUpstreamColumnId;

    float x,y, x1,y1, x2,y2, xA1,yA1, xA2,yA2;
    PARC_BLOCK arcPtr;

    int lineType;

    PNODE_BLOCK node1Ptr, node2Ptr;

    int node1, node2;

    float mCentroid, yIntCentroid;
    float m1, m2, b1, b2, d;
    float xBar, yBar;
    double d2;
    float TOLERANCE = 0.001;

```

```

d = 0.0;

upstreamElementId = flowFacePtr->upstreamElementId;
upstreamElementPtr = lookupElementPtrF(upstreamElementId);
if(upstreamElementPtr != NULL)
{
    upstreamColumnId = upstreamElementPtr->columnId;
    upstreamColumnPtr = lookupColumnPtrF(upstreamColumnId);
}
else
    upstreamColumnPtr = NULL;

downstreamElementId = flowFacePtr->downstreamElementId;
downstreamElementPtr = lookupElementPtrF(downstreamElementId);
if(downstreamElementPtr != NULL)
{
    downstreamColumnId = downstreamElementPtr->columnId;
    downstreamColumnPtr = lookupColumnPtrF(downstreamColumnId);
}
else
    downstreamColumnPtr = NULL;

if( (flowFacePtr != NULL) && (upstreamColumnPtr == NULL) )
{
    arcPtr = flowFacePtr->arcPtr;
    node1 = arcPtr->nodeId[0];
    node2 = arcPtr->nodeId[2];

    node1Ptr = findNodePtrF(node1);
    xA1 = node1Ptr->coordinates[0];
    yA1 = node1Ptr->coordinates[1];

```

```

node2Ptr = findNodePtrF(node2);
xA2 = node2Ptr->coordinates[0];
yA2 = node2Ptr->coordinates[1];
x1 = (xA1 + xA2) / 2.0;
y1 = (yA1 + yA2) / 2.0;

x2 = downstreamColumnPtr->centroidX;
y2 = downstreamColumnPtr->centroidY;

d2 = (x1-x2)*(x1-x2) + (y1-y2)*(y1-y2);
d2 = sqrt(d2);

d = d2;

return(d);
}

if( (flowFacePtr != NULL) && (downstreamColumnPtr != NULL) )
{
    x1 = upstreamColumnPtr->centroidX;
    y1 = upstreamColumnPtr->centroidY;

    x2 = downstreamColumnPtr->centroidX;
    y2 = downstreamColumnPtr->centroidY;

    /* Set line type */
    if( (y2-y1) < TOLERANCE )
        lineType = HORIZONTAL;
    else
        if( (x2-x1) < TOLERANCE )
            lineType = VERTICAL;
}

```



```

else
    lineType = INBETWEEN;

switch(lineType)
{
    case HORIZONTAL:
        arcPtr = flowFacePtr->arcPtr;
        node1 = arcPtr->nodeId[0];
        node2 = arcPtr->nodeId[2];

        node1Ptr = findNodePtrF(node1);
        xA1 = node1Ptr->coordinates[0];
        yA1 = node1Ptr->coordinates[1];

        node2Ptr = findNodePtrF(node2);
        xA2 = node2Ptr->coordinates[0];
        yA2 = node2Ptr->coordinates[1];

        xBar = (xA1 + xA2) / 2.0;
        yBar = (yA1 + yA2) / 2.0;

        d2 = xBar - x2;
        if( d2 < 0.0) d2 = -d2;

        d = d2;

        break;

    case VERTICAL:
        arcPtr = flowFacePtr->arcPtr;
        node1 = arcPtr->nodeId[0];
        node2 = arcPtr->nodeId[2];

```

```

node1Ptr = findNodePtrF(node1);
xA1 = node1Ptr->coordinates[0];
yA1 = node1Ptr->coordinates[1];

node2Ptr = findNodePtrF(node2);
xA2 = node2Ptr->coordinates[0];
yA2 = node2Ptr->coordinates[1];

xBar = (xA1 + xA2) / 2.0;
yBar = (yA1 + yA2) / 2.0;

d2 = yBar - y2;
if( d2 < 0.0) d2 = -d2;

d = d2;

break;

case INBETWEEN:

    m1 = (x2-x1) / (y2-y1);
    b1 = y1-m1*x1;

    /* Calculate equation of arc */
    arcPtr = flowFacePtr->arcPtr;
    node1 = arcPtr->nodeId[0];
    node2 = arcPtr->nodeId[2];

    node1Ptr = findNodePtrF(node1);
    xA1 = node1Ptr->coordinates[0];
    yA1 = node1Ptr->coordinates[1];

```

```

node2Ptr = findNodePtrF(node2);
xA2 = node2Ptr->coordinates[0];
yA2 = node2Ptr->coordinates[1];

m2 = (xA2-xA1) / (yA2-yA1);
b2 = yA1-m2*xA1;

/* Calculate intersection location of
the two lines */
x = (b2-b1) / (m1-m2);
y = (m1*b2 - m2*b1) / (m1-m2);

d2 = (x-x2)*(x-x2) + (y-y2)*(y-y2);
d2 = sqrt(d2);

d = d2;

break;
}
}

return(d);
}

/* _____ */
float
calculate_BIL_F( PFLOWFACE_BLOCK flowFacePtr )

```

```

{
    PELEMENT_BLOCK upstreamElementPtr;
    int upstreamElementId;

    PCOLUMN_BLOCK upstreamColumnPtr;
    int upstreamColumnId;

    PELEMENT_BLOCK farUpstreamElementPtr;
    int farUpstreamElementId;

    PCOLUMN_BLOCK farUpstreamColumnPtr;
    int farUpstreamColumnId;

    float x1,y1, x2,y2;

    float d;
    double d2;

    upstreamElementId = flowFacePtr->upstreamElementId;
    upstreamElementPtr = lookupElementPtrF(upstreamElementId);
    if(upstreamElementPtr != NULL)
    {
        upstreamColumnId = upstreamElementPtr->columnId;
        upstreamColumnPtr = lookupColumnPtrF(upstreamColumnId);
    }
    else
        upstreamColumnPtr = NULL;

    farUpstreamElementId = flowFacePtr->farUpstreamElementId;
    farUpstreamElementPtr = lookupElementPtrF(farUpstreamElementId);
    if( (upstreamColumnPtr != NULL) && (farUpstreamElementPtr != NULL) )

```

```

{
    farUpstreamColumnId = farUpstreamElementPtr->columnId;
    farUpstreamColumnPtr = lookupColumnPtrF(farUpstreamColumnId);

    x1 = upstreamColumnPtr->centroidX;
    y1 = upstreamColumnPtr->centroidY;

    x2 = farUpstreamColumnPtr->centroidX;
    y2 = farUpstreamColumnPtr->centroidY;

    d2 = (x1-x2)*(x1-x2) + (y1-y2)*(y1-y2);
    d2 = sqrt(d2);
    d = d2;

}
else
    d = 0.0;

return(d);

}

/*
*/

float
calculate_BIR_F( PFLOWFACE_BLOCK flowFacePtr )
{
    PELEMENT_BLOCK downstreamElementPtr;
    int    downstreamElementId;

    PCOLUMN_BLOCK  downstreamColumnPtr;
    int    downstreamColumnId;

```

```

PELEMENT_BLOCK farDownstreamElementPtr;
int farDownstreamElementId;

PCOLUMN_BLOCK farDownstreamColumnPtr;
int farDownstreamColumnId;

float x1,y1, x2,y2;

float d;
double d2;

downstreamElementId = flowFacePtr->downstreamElementId;
downstreamElementPtr = lookupElementPtrF(downstreamElementId);
if(downstreamElementPtr != NULL)
{
    downstreamColumnId = downstreamElementPtr->columnId;
    downstreamColumnPtr = lookupColumnPtrF(downstreamColumnId);
}
else
    downstreamColumnPtr = NULL;

farDownstreamElementId = flowFacePtr->farDownstreamElementId;
farDownstreamElementPtr = lookupElementPtrF(farDownstreamElementId);
if( (downstreamColumnPtr != NULL) && (farDownstreamElementPtr != NULL) )
{
    farDownstreamColumnId = farDownstreamElementPtr->columnId;
    farDownstreamColumnPtr = lookupColumnPtrF(farDownstreamColumnId);

    x1 = downstreamColumnPtr->centroidX;
    y1 = downstreamColumnPtr->centroidY;

```

```

x2 = farDownstreamColumnPtr->centroidX;
y2 = farDownstreamColumnPtr->centroidY;

    d2 = (x1-x2)*(x1-x2) + (y1-y2)*(y1-y2);
    d2 = sqrt(d2);

    d = d2;
    }
    else
    d = 0.0;

return(d);
}
/* _____ */

void calculateDistanceBetweenCentroidsF()
{
    FLOWFACE_BLOCK *flowFacePtr;

    /* Examine each cell face and calculate
       the required distances */

    flowFacePtr = pHeadFlowFaceListBlockPtr;

    while( (flowFacePtr != NULL) && (flowFacePtr->orientation == HORIZONTAL) )

```

```

{
    if( (flowFacePtr->type == INTERNAL) || (flowFacePtr->type == BOUNDARY) )
    {
        /* BIL = Distance between farUpstreamElement
        centroid and upstreamElement centroid.

        BI = Distance between upstreamElement
        centroid and the downstreamElement
        centroid.

        BIR = Distance between downstreamElement
        centroid and farDownstreamElement
        centroid.

        BID = Distance between flowface and the
        downstreamElement. */

        /* Calculate BI! */

        flowFacePtr->distanceBetweenCentroids =
        calculate_BI_F(flowFacePtr);

        /* Calculate BID! */

        flowFacePtr->downstreamDistanceBetweenCentroidAndFace =
        calculate_BID_F(flowFacePtr);

        /* Calculate BIL! */
    }
}

```



```

flowFacePtr->distanceBetweenUpstreamCentroids =
    calculate_BIL_F(flowFacePtr);

    /* Calculate BIR! */

    flowFacePtr->distanceBetweenDownstreamCentroids=
        calculate_BIR_F(flowFacePtr);
}

/* Go to next flow face */

flowFacePtr = flowFacePtr->pNextFlowFaceBlockPtr;
}

}

/*
_____*

int iCheckIfTwoListsAreTheSameF(int listA[3], int listB[3])
{
    int i,j;

    int list1[3], list2[3];

    int templnt;

    for(i=0; i<3; i++)
        list1[i] = listA[i];

```

```

for(i=0; i<3; i++)
for(j=i+1; j<3; j++)
if(list1[i] > list1[j])
{ tempInt = list1[i];
list1[i] = list1[j];
list1[j] = tempInt;
}

for(i=0; i<3; i++)
list2[i] = listB[i];

for(i=0; i<3; i++)
for(j=i+1; j<3; j++)
if(list2[i] > list2[j])
{ tempInt = list2[i];
list2[i] = list2[j];
list2[j] = tempInt;
}

if( (list1[0] == list2[0]) && (list1[1] == list2[1]) && (list1[2] == list2[2]) )
return(TRUE);
else
return(FALSE);
}

/* _____ */

PARC_BLOCK checkIfArcExistsF( int list[3] )

```

```

{
    ARC_BLOCK *arcPtr;
    |
    int numbersAreTheSame;

    int i;

    arcPtr = pHeadArcListBlockPtr;

    while(arcPtr != NULL)
    { for(i=0; i<3; i++)
      {
          numbersAreTheSame = iCheckIfTwoListsAreTheSameF(&arcPtr->nodeId[0],list);
          if(numbersAreTheSame)
              return(arcPtr);
      }
    }

    arcPtr = arcPtr->pNextArcBlockPtr;
}

return(NULL);
}

/* _____ */

void
readElementConnectionFile()
{
    FILE *inputf;
    char dummyStr[80];
    COLUMN_BLOCK *currentColumnPtr;

```

```

NODE_BLOCK *currentNodePtr;
int i, lineType;
int arcCount;
int nodeInArc[3];
ARC_BLOCK *arcPtr;
int numberOfNodesInCell;
int nodeList[20];
int index;

/* Open the element to node connection
   table file */

inputf = fopen("r102.geo", "r");

if(inputf == NULL)
{ printf("Unable to open 'r102.geo'\n");
  exit(0);
}

while(1)
{
    fscanf(inputf, "%s", dummyStr);

    if( !feof(inputf) ) break;

    lineType = OTHERSTUFF;

    if( !strcmp(dummyStr, "GE") )
        lineType = GE;
    else
        /* strcmp returns 0 if args same */
        /* foef returns a nonzero (TRUE) value
           after the FIRST read BEYOND the end
           of file! */
        /* Read till end of file */
}

```

```

{ if( !strcmp(dummyStr,"GNN") )
  lineType = GNN;
}

switch(lineType)

{ case GE:

    /* Note that we will number our
       elements as they are numbered
       in RMA10 for the surface layer.

       So we read the element ID from
       the connection file.      */

    currentColumnPtr = allocateNewColumnBlockFO();

    currentColumnPtr->numberOfLayers = NUMBER_OF_LAYERS;

    fscanf(inputf, "%d", &currentColumnPtr->columnId);

    for(i=0; i<8; i++)
        fscanf(inputf, "%d", &nodeList[i]);

    numberOfNodesInCell = 0;
    for(i=0; i<8; i++)
        if(nodeList[i] != 0)
            numberOfNodesInCell++;

    nodeList[numberOfNodesInCell] = nodeList[0];

    /* Repeat first node Id as last node */

    if(numberOfNodesInCell == 8)
    { currentColumnPtr->columnType = TRAPAZOID;

```

```

        currentColumnPtr->arcCount = 4;
    }
    else
    {
        if(numberOfNodesInCell == 6)
        {
            currentColumnPtr->columnType = TRIANGLE;
            currentColumnPtr->arcCount = 3;
        }
    }

    switch(currentColumnPtr->columnType)
    {
        case TRAPAZOID:

            index = 0;
            for(arcCount=0; arcCount<4; arcCount++)
            {
                for(i=0; i<3; i++)
                {
                    if(i != 0) index++;
                    nodeInArc[i] = nodeList[index];
                }

                arcPtr = checkIfArcExistsF( nodeInArc );

                if(arcPtr == NULL)
                {
                    arcPtr = allocateNewArcBlockF();
                    arcPtr->nodeId[0] = nodeInArc[0];
                    arcPtr->nodeId[1] = nodeInArc[1];
                    arcPtr->nodeId[2] = nodeInArc[2];
                }

                currentColumnPtr->arcIds[arcCount] = arcPtr->arcId;
            }
            break;

```

```

case TRIANGLE:
    index = 0;
    for(arcCount=0; arcCount<3; arcCount++)
    {
        for(i=0; i<3; i++)
        {
            if(i != 0) index++;
            nodeInArc[i] = nodeList[index];
        }

        arcPtr = checkIfArcExistsF( nodeInArc );

        if(arcPtr == NULL)
        {
            arcPtr = allocateNewArcBlockF();
            arcPtr->nodeId[0] = nodeInArc[0];
            arcPtr->nodeId[1] = nodeInArc[1];
            arcPtr->nodeId[2] = nodeInArc[2];
        }

        currentColumnPtr->arcIds[arcCount] = arcPtr->arcId;
    }
    break;
}
break;

```

```

case GNN:

    /* Note that we will number our
       nodes as they are numbered
       in RMA10. So we read the node
       id from the connection file. */

    currentNodePtr = allocateNewNodeBlockF();

    fscanf(inputf, "%d", &currentNodePtr->nodeId);

    for(i=0; i<3; i++)
        fscanf(inputf, "%f", &currentNodePtr->coordinates[i]);

    break;

}

}

fclose(inputf);

}

/* _____ */

void
mapColumnsToArcs()
{

```



```

PCOLUMN_BLOCK columnPtr;
PARC_BLOCK arcPtr;
int arcId;
int i, iTemp;

columnPtr = pHeadColumnListBlockPtr;

while(columnPtr != NULL)
{
    /* Each column has 4 potential arcs */

    for(i=0; i<columnPtr->arcCount; i++)
    {
        if(columnPtr->arcIds[i] < 1) continue;
        arcId = columnPtr->arcIds[i];
        arcPtr = findArcPtrF(arcId);

        /* Set so the smaller column id is the
        first in adjacent column list */

        if(arcPtr->adjacentColumn[1] == -1)
        {
            arcPtr->adjacentColumn[1] = columnPtr->columnId;
        }
        else
        {
            if(columnPtr->columnId > arcPtr->adjacentColumn[1])
            {
                arcPtr->adjacentColumn[0] = arcPtr->adjacentColumn[1];
                arcPtr->adjacentColumn[1] = columnPtr->columnId;
            }
            else
        }
    }
}

```

```

        arcPtr->adjacentColumn[0] = columnPtr->columnId;
    }

    {}

    columnPtr = columnPtr->pNextColumnBlockPtr;
}

}

}

/* _____ */

int
searchColumnListForNamedArc(PCOLUMN_BLOCK columnPtr,
    int arcId)

{
    PCOLUMN_BLOCK columnPtr2;

    int i, foundIt;

    columnPtr2 = pHeadColumnListBlockPtr;

    while( columnPtr2 != NULL)
    {
        if(columnPtr2 == columnPtr)
        {
            columnPtr2 = columnPtr2->pNextColumnBlockPtr;
            continue;
        }
    }
}

```

```

foundIt = FALSE;

for(i=0; i<columnPtr2->arcCount; i++)
{ if(columnPtr2->arcIds[i] == arcId)
  foundIt = TRUE;
}

if( foundIt )
  return(columnPtr2->columnId);

columnPtr2 = columnPtr2->pNextColumnBlockPtr;
}

return(-1);
}

/* _____ */

int
iCheckIfArcIsAFlowBoundaryF(PARC_BLOCK arcPtr)
{
  PBOUNDARY_NODE_BLOCK boundaryNodePtr;
  int nodeId, i;
  int foundIt;

  for(i=0; i<3; i++)
  { boundaryNodePtr = pHeadBoundaryNodeBlockPtr;

```

```

foundIt = NO;

while( boundaryNodePtr != NULL)
{ { nodeId = arcPtr->nodeId[i];
  if(boundaryNodePtr->boundaryNodeId == nodeId)
  { foundIt = YES;
    break;
  }

  boundaryNodePtr = boundaryNodePtr->nextBoundaryNodeBlockPtr;
}

if(foundIt == NO)
return(NO);
}

return(YES);
}

/* _____ */

void determineArcTypeF()
{
  PARC_BLOCK arcPtr;
  int result;

  arcPtr = pHeadArcListBlockPtr;

  while(arcPtr != NULL)
  { if((arcPtr->adjacentColumn[0] != -1) && (arcPtr->adjacentColumn[1] != -1))
    arcPtr->type = INTERNAL;
  }
}

```

```

else
{
    result = iCheckIfArcIsAFlowBoundaryF(arcPtr);
    if(result == YES)
    {
        arcPtr->type = BOUNDARY;
    }
    else
    {
        arcPtr->type = WALL;
    }
    arcPtr = arcPtr->pNextArcBlockPtr;
}
}

/* _____ */

void
mapNeighborColumnsForEachColumn()
{
    PCOLUMN_BLOCK columnPtr;

    int arcCount, arcId;
    int otherColumnId;
    int i, first, second, third;

    columnPtr = pHeadColumnListBlockPtr;

    while(columnPtr != NULL)
    {
        for( arcCount=0; arcCount<columnPtr->arcCount; arcCount++)

```

```

{ arcId = columnPtr->arcIds[arcCount];
  otherColumnId = searchColumnListForNamedArc( columnPtr, arcId );
  if(otherColumnId > 0)
  { columnPtr->commonNeighborColumnId[columnPtr->commonNeighborColumnCount] = otherColumnId;
    columnPtr->commonNeighborArcId[columnPtr->commonNeighborColumnCount++] = arcId;
  }
}

columnPtr = columnPtr->pNextColumnBlockPtr;
}
}

/* _____ */

int
iCheckIfCommonNodeInTwoArcsF(PARC_BLOCK arcPtr1, PARC_BLOCK arcPtr2)
{
  int i;

  for(i=0; i<3; i++)
    if( (arcPtr1->nodeId[i] == arcPtr2->nodeId[0])
        ||
        (arcPtr1->nodeId[i] == arcPtr2->nodeId[1])
        ||
        (arcPtr1->nodeId[i] == arcPtr2->nodeId[2]) )
      return(YES);
  return(NO);
}

```

```

/* _____ */

```

```

PARC_BLOCK
findOppositeArcInAColumnF(int columnId, int arcId)
{
    PCOLUMN_BLOCK columnPtr;
    PARC_BLOCK arcPtr, arcPtr2, arcPtr3;
    int nodeId, nodeId2, nodeId3;
    PNODE_BLOCK nodePtr, nodePtr2, nodePtr3;
    int i, result;
    int foundOppositeArc;
    int arcId2;
    float x1, y1, x2, y2;
    double dd;
    float d2, d3;

    columnPtr = lookupColumnPtrF(columnId);

    switch(columnPtr->columnType)
    {
        case TRAPAZOID:
            arcPtr = findArcPtrF(arcId);

            foundOppositeArc = NO;

            for(i=0; i<4; i++)
            {
                arcId2 = columnPtr->arcIds[i];

                if( arcId != arcId2)
                {
                    arcPtr2 = findArcPtrF(arcId2);

```

```

result = iCheckIfCommonNodeInTwoArcsF(arcPtr,arcPtr2);
if(result == NO)
{
    foundOppositeArc = YES;
    break;
}
}
}

if(foundOppositeArc == YES)
    return(arcPtr2);
else
    return(NULL);
break;

case TRIANGLE:
    arcPtr = findArcPtrF(arcId);

    for(i=0; i<3; i++)
        if(columnPtr->arcIds[i]) break;

    if(i == 0)
    {
        arcPtr2 = findArcPtrF(columnPtr->arcIds[1]);
        arcPtr3 = findArcPtrF(columnPtr->arcIds[2]);
    }
    else
    {
        if(i == 1)
        {
            arcPtr2 = findArcPtrF(columnPtr->arcIds[0]);
            arcPtr3 = findArcPtrF(columnPtr->arcIds[2]);
        }
        else
        {
            if(i == 2)

```



```

{ arcPtr2 = findArcPtrF(columnPtr->arcIds[0]);
  arcPtr3 = findArcPtrF(columnPtr->arcIds[1]);
}

nodeId = arcPtr->nodeId[1];
nodeId2 = arcPtr2->nodeId[1];
nodeId3 = arcPtr3->nodeId[1];

nodePtr = findNodePtrF(nodeId);
x1 = nodePtr->coordinates[0];
y1 = nodePtr->coordinates[1];

nodePtr2 = findNodePtrF(nodeId2);
x2 = nodePtr->coordinates[0];
y2 = nodePtr->coordinates[1];

dd = (x1-x2)*(x1-x2) + (y1-y2)*(y1-y2);
dd = sqrt(dd);
d2 = dd;

nodePtr3 = findNodePtrF(nodeId3);
x2 = nodePtr->coordinates[0];
y2 = nodePtr->coordinates[1];

dd = (x1-x2)*(x1-x2) + (y1-y2)*(y1-y2);
dd = sqrt(dd);
d3 = dd;

if(d2 < d3)
    return(arcPtr2);
else
    return(arcPtr3);

```

```

    }

    return(NULL);
}

/* _____ */

void
mapUpstreamAndDownstreamColumnsForEachColumnFO
{
    PCOLUMN_BLOCK columnPtr;
    int i, otherColumnId, otherArcId;
    PARC_BLOCK farArcPtr;

    columnPtr = pHeadColumnListBlockPtr;

    while(columnPtr != NULL)
    {
        for(i=0; i<columnPtr->arcCount; i++)
        {
            otherColumnId = columnPtr->commonNeighborColumnId[i];
            otherArcId = columnPtr->commonNeighborArcId[i];
            if(otherColumnId != -1)
            {
                farArcPtr = findOppositeArcInAColumnF(otherColumnId, otherArcId);
                if(farArcPtr->adjacentColumn[0] == otherColumnId)
                {
                    columnPtr->commonNeighbor2ColumnId[i] = farArcPtr->adjacentColumn[1];
                }
                else
                {
                    columnPtr->commonNeighbor2ColumnId[i] = farArcPtr->adjacentColumn[0];
                }
            }
            else
            {
                columnPtr->commonNeighbor2ColumnId[i] = -1;
            }
        }
    }
}

```

```

columnPtr = columnPtr->pNextColumnBlockPtr;
}
}
}
/*
*/

void
createElementList()
{
ELEMENT_BLOCK *elementPtr;
ELEMENT_BLOCK *elementAbovePtr;
COLUMN_BLOCK *columnPtr;

int iMaximumNumberOfLayers;
int iCurrentCellLayerId;
int iNumberOfCells;
int i;
int lastRemainingElementId;

/* Determine maximum number of layers
   in column list */
iMaximumNumberOfLayers = 0;

columnPtr = pHeadColumnListBlockPtr;

while(columnPtr != NULL)
{
if(columnPtr->numberOfLayers > iMaximumNumberOfLayers)
iMaximumNumberOfLayers = columnPtr->numberOfLayers;

columnPtr = columnPtr->pNextColumnBlockPtr;
}

```

```

iCurrentCellLayerId = 1;
iNumberOfCells = 0;
/* Do surface layer first */
/* Column IDs same as element IDs in
   surface layer. */
columnPtr = pHeadColumnListBlockPtr;
while(columnPtr != NULL)
{
    elementPtr = allocateNewElementBlockFO();
    columnPtr->elementPtr = elementPtr;
    columnPtr->surfaceElementPtr = elementPtr;
    elementPtr->columnId = columnPtr->columnId;
    elementPtr->elementType = columnPtr->columnType;
    elementPtr->arcCount = columnPtr->arcCount;
    elementPtr->layerId = iCurrentCellLayerId;
    elementPtr->elementId = columnPtr->columnId;
    elementPtr->rma10ElementId = elementPtr->elementId;
    iNumberOfCells++;
    columnPtr = columnPtr->pNextColumnBlockPtr;
}
lastRma10ElementId = elementPtr->rma10ElementId;

```

```

/* Now do all subsurface layers */
for(iCurrentCellLayerId = 2;
   iCurrentCellLayerId <= iMaximumNumberOfLayers;
   iCurrentCellLayerId++)
{
    columnPtr = pHeadColumnListBlockPtr;

    while(columnPtr != NULL)
    {
        if(iCurrentCellLayerId <= columnPtr->numberOfLayers )
        {
            elementPtr = allocateNewElementBlockFQ();

            elementPtr->columnId = columnPtr->columnId;

            elementPtr->elementType = columnPtr->columnType;

            elementPtr->arcCount = columnPtr->arcCount;

            elementAbovePtr = columnPtr->elementPtr;

            elementPtr->elementAbovePtr = elementAbovePtr;

            elementAbovePtr->elementBelowPtr = elementPtr;

            columnPtr->elementPtr = elementPtr;

            elementPtr->layerId = iCurrentCellLayerId;

            iNumberOfCells++;

            elementPtr->elementId = iNumberOfCells;

```

```

    }

    columnPtr = columnPtr->pNextColumnBlockPtr;

    -
    }

    }

    /* Now number all elements with their
       rma10ElementId */

    columnPtr = pHeadColumnListBlockPtr;

    while(columnPtr != NULL)
    {
        elementPtr = columnPtr->surfaceElementPtr;
        while(elementPtr->elementBelowPtr != NULL)
            elementPtr = elementPtr->elementBelowPtr;

        while(elementPtr->elementAbovePtr != NULL)
        {
            elementPtr->rma10ElementId = ++lastRma10ElementId;
            elementPtr = elementPtr->elementAbovePtr;
        }

        columnPtr = columnPtr->pNextColumnBlockPtr;
    }

    }

    /* _____ */

    void
    mapElementToNeighborElements()

```

```

{
    PCOLUMN_BLOCK columnPtr, otherColumnPtr, farColumnPtr;
    int columnId, otherColumnId, farColumnId;

    int i;

    int currentLayerId;
    int iMaximumNumberOfLayers;

    PELEMENT_BLOCK elementPtr, otherElementPtr, farElementPtr;

    /* Determine maximum number of layers
       in column list */
    iMaximumNumberOfLayers = 0;

    columnPtr = pHeadColumnListBlockPtr;

    while(columnPtr != NULL)
    {
        if(columnPtr->numberOfLayers > iMaximumNumberOfLayers)
            iMaximumNumberOfLayers = columnPtr->numberOfLayers;

        columnPtr = columnPtr->pNextColumnBlockPtr;
    }

    currentLayerId = 1;

    while(currentLayerId <= iMaximumNumberOfLayers)
    {
        columnPtr = pHeadColumnListBlockPtr;
    }

```

```

while(columnPtr != NULL)
{
    elementPtr = columnPtr->surfaceElementPtr;

    while(elementPtr->layerId < currentLayerId)
        elementPtr = elementPtr->elementBelowPtr;

    if(elementPtr != NULL)
    {
        for(i=0; i<columnPtr->arcCount; i++)
        {
            otherColumnId = columnPtr->commonNeighborColumnId[i];
            if(otherColumnId != -1)
            {
                otherColumnPtr = lookupColumnPtrF(otherColumnId);
                otherElementPtr = otherColumnPtr->surfaceElementPtr;

                while(otherElementPtr->layerId < currentLayerId)
                    otherElementPtr = otherElementPtr->elementBelowPtr;

                if(otherElementPtr != NULL)
                    elementPtr->commonNeighborElementId[i] = otherElementPtr->elementId;
                else
                    elementPtr->commonNeighborElementId[i] = -1;
            }
        }
        farColumnId = columnPtr->commonNeighbor2ColumnId[i];
        if(farColumnId != -1)
        {
            farColumnPtr = lookupColumnPtrF(farColumnId);
            farElementPtr = farColumnPtr->surfaceElementPtr;

            while(farElementPtr->layerId < currentLayerId)
                farElementPtr = farElementPtr->elementBelowPtr;
        }
    }
}

```



```

        if(farElementPtr != NULL)
            elementPtr->commonNeighbor2ElementId[i] = farElementPtr->elementId;
        else
            elementPtr->commonNeighbor2ElementId[i] = -1;
    }
}

columnPtr = columnPtr->pNextColumnBlockPtr;
}

currentLayerId++;
}

}

/* _____ */

void
generateHorizontalFlowFaceListF()
{
    PCOLUMN_BLOCK columnPtr;
    int iMaximumNumberOfLayers;
    int currentLayerId;
    PARC_BLOCK arcPtr;
    PFLOWFACE_BLOCK flowFacePtr;
    PELEMENT_BLOCK elementPtr;

```

```

int    result;
int    columnId;

/* Determine maximum number of layers
   in column list */
iMaximumNumberOfLayers = 0;

columnPtr = pHeadColumnListBlockPtr;

while(columnPtr != NULL)
{
    if(columnPtr->numberOfLayers > iMaximumNumberOfLayers)
        iMaximumNumberOfLayers = columnPtr->numberOfLayers;

    columnPtr = columnPtr->pNextColumnBlockPtr;
}

currentLayerId = 1;

while(currentLayerId <= iMaximumNumberOfLayers)
{
    arcPtr = pHeadArcListBlockPtr;

    while(arcPtr != NULL)
    {
        flowFacePtr = allocateNewFlowFaceBlockFO;

        flowFacePtr->orientation = HORIZONTAL;

        flowFacePtr->layerId = currentLayerId;
    }
}

```

```

flowFacePtr->arcPtr = arcPtr;

flowFacePtr->adjacentColumn[0] = arcPtr->adjacentColumn[0];
flowFacePtr->adjacentColumn[1] = arcPtr->adjacentColumn[1];

columnId = arcPtr->adjacentColumn[0];
if(columnId != -1)
{
    columnPtr = lookupColumnPtrF(columnId);
    elementPtr = columnPtr->surfaceElementPtr;

    while(elementPtr->layerId < currentLayerId)
        elementPtr = elementPtr->elementBelowPtr;

    if(elementPtr != NULL)
        flowFacePtr->adjacentElement[0] = elementPtr->elementId;
    else
        flowFacePtr->adjacentElement[0] = -1;
}

columnId = arcPtr->adjacentColumn[1];
if(columnId != -1)
{
    columnPtr = lookupColumnPtrF(columnId);
    elementPtr = columnPtr->surfaceElementPtr;

    while(elementPtr->layerId < currentLayerId)
        elementPtr = elementPtr->elementBelowPtr;

    if(elementPtr != NULL)
        flowFacePtr->adjacentElement[1] = elementPtr->elementId;
    else
        flowFacePtr->adjacentElement[1] = -1;
}

switch(arcPtr->type)

```

```

{
    case INTERNAL:
        flowFacePtr->type = INTERNAL;
        break;

    case BOUNDARY:
        flowFacePtr->type = BOUNDARY;
        break;

    case WALL:
        flowFacePtr->type = WALL;
        break;
}

arcPtr = arcPtr->pNextArcBlockPtr;
}

currentLayerId++;
}

}

/* _____ */

void
mapHorizontalFlowFaces()
{
    PELEMENT_BLOCK elementPtr;
    PFLOWFACE_BLOCK flowFacePtr;
    PARC_BLOCK arcPtr, oppositeArcPtr;

```

```

int      foundIt, i;
int      targetElementId;

int      leftElementId, rightElementId;
PELEMENT_BLOCK leftElementPtr, rightElementPtr;
int      leftColumnId, rightColumnId;
int      farLeftColumnId, farRightColumnId;
PCOLUMN_BLOCK farLeftColumnPtr, farRightColumnPtr;
PELEMENT_BLOCK farElementPtr;
int      farLeftElementId, farRightElementId;

flowFacePtr = pHeadFlowFaceListBlockPtr;

while(flowFacePtr != NULL)
{
    switch(flowFacePtr->type)
    {
        case INTERNAL:
            leftElementId = flowFacePtr->adjacentElement[0];
            rightElementId = flowFacePtr->adjacentElement[1];

            flowFacePtr->upstreamElementId = leftElementId;
            flowFacePtr->downstreamElementId = rightElementId;

            leftElementPtr = lookupElementPtrF(leftElementId);

            foundIt = NO;
            for(i=0; i<leftElementPtr->arcCount; i++)
            {
                targetElementId = leftElementPtr->commonNeighborElementId[i];
                if(targetElementId == rightElementId)
                { foundIt = YES;
                  break;
                }
            }
        }
    }
}

```

```

    }
}

if(foundIt == YES)
{
    flowFacePtr->farDownstreamElementId =
    leftElementPtr->commonNeighbor2ElementId[i];
}
else
    flowFacePtr->farDownstreamElementId = -1;

rightElementPtr = lookupElementPtrF(rightElementId);

foundIt = NO;
for(i=0; i<rightElementPtr->arcCount; i++)
{
    targetElementId = rightElementPtr->commonNeighborElementId[i];
    if(targetElementId == leftElementId)
    {
        foundIt = YES;
        break;
    }
}

if(foundIt == YES)
{
    flowFacePtr->farUpstreamElementId =
    rightElementPtr->commonNeighbor2ElementId[i];
}
else
    flowFacePtr->farUpstreamElementId = -1;

break;

```

```

case BOUNDARY:
    leftElementId = flowFacePtr->adjacentElement[0];
    rightElementId = flowFacePtr->adjacentElement[1];

    flowFacePtr->upstreamElementId = leftElementId;
    flowFacePtr->downstreamElementId = rightElementId;

    if(leftElementId == -1)
        flowFacePtr->farUpstreamElementId = -1;
    else
        { arcPtr = flowFacePtr->arcPtr;

        leftElementPtr = lookupElementPtrF(leftElementId);
        leftColumnId = leftElementPtr->columnId;

        oppositeArcPtr = findOppositeArcInAColumnF(leftColumnId, arcPtr->arcId);
        if(oppositeArcPtr->adjacentColumn[0] == leftColumnId)
            farLeftColumnId = oppositeArcPtr->adjacentColumn[1];
        else
            farLeftColumnId = oppositeArcPtr->adjacentColumn[0];

        farLeftColumnPtr = lookupColumnPtrF(farLeftColumnId);
        farElementPtr = farLeftColumnPtr->surfaceElementPtr;

        while(farElementPtr->layerId < leftElementPtr->layerId)
            farElementPtr = farElementPtr->elementBelowPtr;

        if(farElementPtr != NULL)
            farLeftElementId = farElementPtr->elementId;
        else
            farLeftElementId = -1;

        flowFacePtr->farUpstreamElementId = farLeftElementId;

```

```

    }

    if(rightElementId == -1)
        flowFacePtr->farDownstreamElementId = -1;
    else
    { arcPtr = flowFacePtr->arcPtr;

        rightElementPtr = lookupElementPtrF(rightElementId);
        rightColumnId = rightElementPtr->columnId;

        oppositeArcPtr = findOppositeArcInAColumnF(rightColumnId,
            arcPtr->arcId);

        if(oppositeArcPtr->adjacentColumn[0] == rightColumnId)
            farRightColumnId = oppositeArcPtr->adjacentColumn[1];
        else
            farRightColumnId = oppositeArcPtr->adjacentColumn[0];

        farRightColumnPtr = lookupColumnPtrF(farRightColumnId);
        farElementPtr = farRightColumnPtr->surfaceElementPtr;

        while(farElementPtr->layerId < rightElementPtr->layerId)
            farElementPtr = farElementPtr->elementBelowPtr;

        if(farElementPtr != NULL)
            farRightElementId = farElementPtr->elementId;
        else
            farRightElementId = -1;

        flowFacePtr->farDownstreamElementId = farRightElementId;
    }

    break;

```



```

case WALL:
    break;
    }

    flowFacePtr = flowFacePtr->pNextFlowFaceBlockPtr;
    }

    }

    /* _____ */

void
mapVerticalFlowFaces()
{
    PELEMENT_BLOCK elementPtr;
    PFLOWFACE_BLOCK flowFacePtr;

    PCOLUMN_BLOCK columnPtr;
    PELEMENT_BLOCK farUpstreamElementPtr,
        upstreamElementPtr,
        downstreamElementPtr,
        farDownstreamElementPtr;

    /* For FEM RMA10 .....
       POSITIVE FLOW IS TAKEN TO BE
       UP! IRREGARDLESS of other
       conventions */

```

```

/* ICM will have vertical flow faces
   numbered from the bottom up with
   and POSITIVE flow taken to be up */

columnPtr = pHeadColumnListBlockPtr;

while(columnPtr != NULL)
{
    elementPtr = columnPtr->surfaceElementPtr;
    while(elementPtr->elementBelowPtr != NULL)
        elementPtr = elementPtr->elementBelowPtr;

    downstreamElementPtr = elementPtr->elementAbovePtr;

    while(downstreamElementPtr != NULL)
    {
        farDownstreamElementPtr = downstreamElementPtr->elementAbovePtr;
        upstreamElementPtr = downstreamElementPtr->elementBelowPtr;
        farUpstreamElementPtr = upstreamElementPtr->elementBelowPtr;

        flowFacePtr = allocateNewFlowFaceBlockFF();
        flowFacePtr->orientation = VERTICAL;

        flowFacePtr->type= INTERNAL;
        downstreamElementPtr->bottomFlowFaceId = flowFacePtr->flowFaceId;

        if(farUpstreamElementPtr != NULL)
            flowFacePtr->farUpstreamElementId = farUpstreamElementPtr->elementId;
        else
            flowFacePtr->farUpstreamElementId = -1;

        flowFacePtr->upstreamElementId = upstreamElementPtr->elementId;
        flowFacePtr->downstreamElementId = downstreamElementPtr->elementId;
    }
}

```

```

    if(farDownstreamElementPtr != NULL)
        flowFacePtr->farDownstreamElementId = farDownstreamElementPtr->elementId;
    else
        flowFacePtr->farDownstreamElementId = -1;

    downstreamElementPtr = downstreamElementPtr->elementAbovePtr;
}

columnPtr = columnPtr->pNextColumnBlockPtr;
}

}

/* _____ */

PARC_BLOCK
findArcPtrF(int arcId)
{
    PARC_BLOCK arcPtr;

    arcPtr = pHeadArcListBlockPtr;

    while(arcPtr != NULL)
    {
        if(arcPtr->arcId == arcId)
            return(arcPtr);
    }
}

```

```

    arcPtr = arcPtr->pNextArcBlockPtr;
}

return(NULL);
}

/* _____ */

PNODE_BLOCK
findNodePtrF(int nodeId)
{
    PNODE_BLOCK nodePtr;

    nodePtr = pHeadNodeBlockPtr;

    while(nodePtr != NULL)
    {
        if(nodePtr->nodeId == nodeId)
            return(nodePtr);

        nodePtr = nodePtr->nextNodeBlockPtr;
    }

    return(NULL);
}

/* _____ */

```

```

PNODE_BLOCK
lookupNodePtrF(int nodeId)
{
    PNODE_BLOCK nodePtr;

    if(lookupNodePtrArray == NULL)
    {
        lookupNodePtrArray =
            (PNODE_BLOCK *)calloc(globalNodeCount+1, sizeof(PNODE_BLOCK));

        nodePtr = pHeadNodeBlockPtr;

        while(nodePtr != NULL)
        {
            lookupNodePtrArray[nodePtr->nodeId] = nodePtr;

            nodePtr = nodePtr->nextNodeBlockPtr;
        }
    }

    if(nodeId > globalNodeCount)
        return(NULL);
    else
        return(lookupNodePtrArray[nodeId]);
}

```

```

/* _____ */

PCOLUMN_BLOCK
findColumnPtr(int columnId)
{
    PCOLUMN_BLOCK columnPtr;

    columnPtr = pHeadColumnListBlockPtr;
    while(columnPtr != NULL)
    {
        if(columnPtr->columnId == columnId)
            return(columnPtr);

        columnPtr = columnPtr->pNextColumnBlockPtr;
    }

    return(NULL);
}

/* _____ */

PCOLUMN_BLOCK
lookupColumnPtrF(int columnId)
{

```

```

PCOLUMN_BLOCK columnPtr;

if (lookupColumnPtrArray == NULL)
{
    lookupColumnPtrArray =
        (PCOLUMN_BLOCK *)calloc (globalColumnCount+1,sizeof (PCOLUMN_BLOCK));

    ColumnPtr = pHeadColumnListBlockPtr;

    while ( columnPtr != NULL )
    {
        lookupColumnPtrArray[columnPtr -> columnId] = columnPtr;

        ColumnPtr = columnPtr -> pNextColumnBlockPtr;
    }
}

if ( (columnId < 1) || (columnId > globalColumncount) )
    return (NULL);
else
    return ( lookupColumnPtrArray[columnId] );
}

/* _____ */
PELEMENT_BLOCK
LookupElementPtrF ( int elementId)
{
    PELEMENT_BLOCK elementPtr;

```

```

if(!lookupElementPtrArray == NULL)
{
    lookupElementPtrArray =
        (PELEMENT_BLOCK *)calloc(globalElementCount+1,sizeof(PELEMENT_BLOCK));

    elementPtr = pHeadElementListBlockPtr;

    while(elementPtr != NULL)
    {
        lookupElementPtrArray[elementPtr->elementId] = elementPtr;

        elementPtr = elementPtr->pNextElementBlockPtr;
    }
}

if( (elementId < 1) || (elementId > globalElementCount))
    return(NULL);
else
    return(lookupElementPtrArray[elementId]);
}

/* _____ */

PFLOWFACE_BLOCK

lookupFlowFacePtrF(int flowFaceId)

```



```

{
    PFLOWFACE_BLOCK flowFacePtr;

    if(lookupFlowFacePtrArray == NULL)
    {
        lookupFlowFacePtrArray =
            (PFLOWFACE_BLOCK *)calloc(globalFlowFaceCount+1, sizeof(PFLOWFACE_BLOCK));

        flowFacePtr = pHeadFlowFaceListBlockPtr;

        while(flowFacePtr != NULL)
        {
            lookupFlowFacePtrArray[flowFacePtr->flowFaceId] = flowFacePtr;

            flowFacePtr = flowFacePtr->pNextFlowFaceBlockPtr;
        }
    }

    if( (flowFaceId < 1) || (flowFaceId > globalFlowFaceCount))
        return(NULL);
    else
        return(lookupFlowFacePtrArray[flowFaceId]);
}

/* _____ */

```

```

void
setFlowFaceIdentifierTags()
{
    PFLOWFACE_BLOCK flowFacePtr;
    PARC_BLOCK arcPtr;
    int surfaceCenterNodeId;
    int topCenterNodeId;
    int layerFlowFacelsIn;
    PELEMENT_BLOCK elementPtr;
    int elementId;

    flowFacePtr = pHeadFlowFaceListBlockPtr;

    while(flowFacePtr != NULL)
    {
        if(flowFacePtr->orientation == HORIZONTAL)
        {
            arcPtr = flowFacePtr->arcPtr;

            surfaceCenterNodeId = arcPtr->nodeId[1];

            layerFlowFacelsIn = flowFacePtr->layerId;

            if(layerFlowFacelsIn == 1)
                topCenterNodeId = surfaceCenterNodeId;
            else
                topCenterNodeId =
                    surfaceNodeList[surfaceCenterNodeId].nref + (layerFlowFacelsIn-1);

            flowFacePtr->identifierTag = topCenterNodeId;
        }
        else
            if(flowFacePtr->orientation == VERTICAL)

```

```

{
    elementId = flowFacePtr->upstreamElementId;
    elementPtr = lookupElementPtrF(elementId);
    flowFacePtr->identifierTag = elementPtr->rma10ElementId;

    /* Check if upstream cell is a surface
       cell. If it is then the identifier
       is taken to be the flow face's
       downstream element's rma10ElementId.
       IF the flow faces upstream element
       is not in the surface layer, then
       it must be in a layer beneath the
       surface layer. All vertical flow
       faces beneath the first vertical
       flow face in a column WILL HAVE THE
       WRONG SENSE OF FLUX when the fluxes
       are read in from the hydrodynamic
       file. This is because in RMA10 they
       number elements first in the surface,
       then they start numbering elements
       in the subsurface at the bottom
       layer then go up in the same column
       to the 2nd layer! The flux sense
       in BOTH models is taken to be from
       an element with the smaller element
       id to the larger element id. We will
       indicate a change in flux sign by
       making the identifier tag NEGATIVE */

}

    flowFacePtr = flowFacePtr->pNextFlowFaceBlockPtr;
}

```

```

}

/* _____ */

void
renumberAllFlowFacesForOutput(F)
{
    PFLOWFACE_BLOCK flowFacePtr;
    int    modelFlowFaceId;
    char    faceType, faceOrientation;

    flowFacePtr = pHeadFlowFaceListBlockPtr;

    modelFlowFaceId = 1;

    while(flowFacePtr != NULL)
    {
        switch(flowFacePtr->type)
        { case INTERNAL:
          faceType = 'I';
          break;

          case BOUNDARY:
          faceType = 'B';
          break;

          case WALL:
          faceType = 'W';
          break;
        }
    }

```

```

switch(flowFacePtr->orientation)
{ case HORIZONTAL:
  faceOrientation = 'H';
  break;

  case VERTICAL:
  faceOrientation = 'V';
  break;
}

if( (faceType == 'B') || (faceType == 'I'))
{
  flowFacePtr->modelFlowFaceId = modelFlowFaceId++;
}

flowFacePtr = flowFacePtr->pNextFlowFaceBlockPtr;
}

}

/* _____ */

int
*retrieveAColumnsVerticalFlowFaceInfo( PCOLUMN_BLOCK columnPtr )
{
  PELEMENT_BLOCK elementPtr;
  PFLOWFACE_BLOCK flowFacePtr;

```

```

PELEMENT_BLOCK  upstreamElementPtr;

int  i, flowFaceId;
int  columnFlowFaceCount = 0;

int  *intList;
int  intListIndex = 0;

elementPtr = columnPtr->surfaceElementPtr;
while(elementPtr->elementBelowPtr != NULL)
{ columnFlowFaceCount++;
  elementPtr = elementPtr->elementBelowPtr;
}

/* Make first element in array
   be count of total size of
   array. */

intList = (int *)calloc(columnFlowFaceCount+1, sizeof(int));
intList[intListIndex++] = columnFlowFaceCount;

upstreamElementPtr = elementPtr->elementAbovePtr;

while(upstreamElementPtr != NULL)
{
  flowFaceId = upstreamElementPtr->bottomFlowFaceId;
  intList[intListIndex++] = flowFaceId;
  upstreamElementPtr = upstreamElementPtr->elementAbovePtr;
}

return(intList);
}

```

```

/* _____ */

void
printFlowFaceListF()
{
    PELEMENT_BLOCK elementPtr;
    FLOWFACE_BLOCK *flowFacePtr;
    int flowFaceId;
    FILE *outf;
    char faceType, faceOrientation;
    int modelFlowFaceId;
    int upstreamElementId,
        downstreamElementId,
        farUpstreamElementId,
        farDownstreamElementId;

    PCOLUMN_BLOCK columnPtr;
    int *intList;
    int i, numberInList;

    outf = fopen("FF.out", "w");

    fprintf(outf, " ICM FEM\n");
    elementPtr = pHeadElementListBlockPtr;
    while(elementPtr != NULL)
    {
        fprintf(outf, "%8d %6d\n",
                elementPtr->elementId,

```

```

    elementPtr->rma10ElementId);

    elementPtr = elementPtr->pNextElementBlockPtr;
}

fprintf(outf, "\n FFID ILB IL JR JRB TYPE ORIENT TAG\n");

flowFacePtr = pHeadFlowFaceListBlockPtr;

flowFaceId = 0;
while(flowFacePtr != NULL)
{
    switch(flowFacePtr->type)
    { case INTERNAL:
      faceType = 'I';
      break;

      case BOUNDARY:
      faceType = 'B';
      break;

      case WALL:
      faceType = 'W';
      break;
    }

    switch(flowFacePtr->orientation)
    { case HORIZONTAL:
      faceOrientation = 'H';
      break;

      case VERTICAL:
      faceOrientation = 'V';
      break;
    }
}

```



```

    }

    modelFlowFaceId = flowFacePtr->modelFlowFaceId;

    if(flowFacePtr->farUpstreamElementId != -1)
        farUpstreamElementId = flowFacePtr->farUpstreamElementId;
    else
        farUpstreamElementId = 0;

    if(flowFacePtr->upstreamElementId != -1)
        upstreamElementId = flowFacePtr->upstreamElementId;
    else
        upstreamElementId = 0;

    if(flowFacePtr->downstreamElementId != -1)
        downstreamElementId = flowFacePtr->downstreamElementId;
    else
        downstreamElementId = 0;

    if(flowFacePtr->farDownstreamElementId != -1)
        farDownstreamElementId = flowFacePtr->farDownstreamElementId;
    else
        farDownstreamElementId = 0;

    if( (flowFacePtr->type == BOUNDARY) || (flowFacePtr->type == INTERNAL))
    {
        flowFaceId++;
        fprintf(outf, "%8d %6d %6d %6d %6d %c %c %c %6d\n",
            modelFlowFaceId,
            farUpstreamElementId,
            upstreamElementId,
            downstreamElementId,
            farDownstreamElementId,

```

```

        faceType,
        faceOrientation,
        flowFacePtr->identifierTag);
    }

    flowFacePtr = flowFacePtr->pNextFlowFaceBlockPtr;
}

/* Write out the number of vertical
   flow faces in a column info */

fprintf(outf, "\n    SB    NVF\n");

columnPtr = pHeadColumnListBlockPtr;

while(columnPtr != NULL)
{
    /* Function returns a list of vertical
       flow faces for each column. This
       list is dynamically allocated so
       need to release memory when we
       finish with it. */

    intList = retrieveAColumnsVerticalFlowFaceInfo(columnPtr);
    numberInList = intList[0];
    fprintf(outf, "%8d%8d\n", columnPtr->columnId, numberInList);
    free(intList);

    columnPtr = columnPtr->pNextColumnBlockPtr;
}

```

```

/* Write out the vertical
   flow faces in a column info */

fprintf(outf, "\n SB VFN LIST...\n");

columnPtr = pHeadColumnListBlockPtr;

while(columnPtr != NULL)
{
    /* Function returns a list of vertical
       flow faces for each column. This
       list is dynamically allocated so
       need to release memory when we
       finish with it. */

    intList = retrieveAColumnsVerticalFlowFaceInfo(columnPtr);
    numberInList = intList[0];

    fprintf(outf, " %6d", columnPtr->columnId);
    for(j=1; j<=numberInList; j++)
    { flowFacePtr = lookupFlowFacePtrF(intList[j]);
      modelFlowFaceId = flowFacePtr->modelFlowFaceId;
      fprintf(outf, " %6d", modelFlowFaceId);
    }
    fprintf(outf, "\n");

    free(intList);

    columnPtr = columnPtr->pNextColumnBlockPtr;
}

fclose(outf);

```

```

    }

    /* _____ */

    void
    printGeoFileF()
    {
        FILE *outf;
        PCOLUMN_BLOCK columnPtr;
        PELEMENT_BLOCK elementPtr;
        PELEMENT_BLOCK surfaceElementPtr, bottomElementPtr;
        PELEMENT_BLOCK elementAbovePtr;
        int elementAboveId;
        PFLOWFACE_BLOCK flowFacePtr;
        char faceType;

        float BIL, BI, BID, BIR;

        outf = fopen("geo.out", "w");

        /* Write out for each column, the
           surface element id and its
           corresponding bottom element id */

        fprintf(outf, " SBN BBN\n");

        columnPtr = pHeadColumnListBlockPtr;

        while(columnPtr != NULL)

```

```

{
    elementPtr = columnPtr->surfaceElementPtr;
    surfaceElementPtr = elementPtr;

    while(elementPtr->elementBelowPtr != NULL)
        elementPtr = elementPtr->elementBelowPtr;

    bottomElementPtr = elementPtr;

    fprintf(outf,
        "%6d %6d\n",
        surfaceElementPtr->elementId,
        bottomElementPtr->elementId);

    columnPtr = columnPtr->pNextColumnBlockPtr;
}

/* Now print out boxes above */
fprintf(outf, "\n BU\n");

elementPtr = pHeadElementListBlockPtr;

while(elementPtr != NULL)
{
    elementAbovePtr = elementPtr->elementAbovePtr;
    if(elementAbovePtr != NULL)
        elementAboveId = elementAbovePtr->elementId;
    else
        elementAboveId = 0;

    fprintf(outf, "%6d \n", elementAboveId);
}

```

```

elementPtr = elementPtr->pNextElementBlockPtr;
}

/* Now print out centroid offsets */
fprintf(outf, "\n    BIL    BI    BID    BIR    type    layer\n");

flowFacePtr = pHeadFlowFaceListBlockPtr;
while( (flowFacePtr != NULL) && (flowFacePtr->orientation == HORIZONTAL) )
{
    if( (flowFacePtr->type == BOUNDARY) || (flowFacePtr->type == INTERNAL))
    {
        switch(flowFacePtr->type)
        {
            case INTERNAL:
                faceType = 'I';
                break;

            case BOUNDARY:
                faceType = 'B';
                break;

            case WALL:
                faceType = 'W';
                break;
        }

        BIL = flowFacePtr->distanceBetweenUpstreamCentroids;
        BI = flowFacePtr->distanceBetweenCentroids;
        BID = flowFacePtr->downstreamDistanceBetweenCentroidAndFace;
        BIR = flowFacePtr->distanceBetweenDownstreamCentroids;
    }
}

```

```

fprintf(outf,
        " %10.5e %10.5e %10.5e %10.5e %c %3d\n",
        BIL,BI,BID,BIR,faceType,flowFacePtr->layerId);

/* fprintf(outf, " %15.9e %15.9e %15.9e %15.9e %15.9e\n",BIL,BI,BID,BIR); */

}

flowFacePtr = flowFacePtr->pNextFlowFaceBlockPtr;

}

fclose(outf);

}

/* _____ */

void readBoundaryArcFile()
{
    FILE *infile;
    int i, int1, int2, index;
    char lineBuffer[132];
    int NP, NE, NPM, NEM;
    int surfaceNodeId;
    int ndep, nref;

    BOUNDARY_NODE_BLOCK *boundaryNodePtr;

```

```

infile = fopen("r4icr10.output", "r");
if(infile == NULL)
{ printf("Unable to open 'r4icr10.output'\n");
  fflush(stdout);
  exit(0);
}

/* Skip first 2 lines */
fgetc(lineBuffer, 132, infile);
fgetc(lineBuffer, 132, infile);

fscanf(infile, "%d %d %d %d", &NP, &NE, &NPM, &NEM);

if(NPM > 100000)
{ printf("number of nodes in surface layer is 100000!\n");
  printf("If thats true then take out this line and recompile!\n");
  fflush(stdout);
  exit(0);
}

surfaceNodeList =
(SURFACE_NODE_LIST *)calloc(NPM+1, sizeof(SURFACE_NODE_LIST));

/* Skip first next 4 lines */
for(i=0; i<4; i++)
fgetc(lineBuffer, 132, infile);

for(i=0; i<NPM; i++)
{ fscanf(infile, "%d %d %d", &surfaceNodeId, &ndep, &nref);
  surfaceNodeList[surfaceNodeId].ndep = ndep;
  surfaceNodeList[surfaceNodeId].nref = nref;
}

```



```

/* Skip first next 3 lines */
for(i=0; i<3; i++)
fgets(lineBuffer,132,infile);

fscanf(infile,"%d %d",&int1, &int2);
while(!feof(infile))
{
    if(int1 < 374)
    if( (int2 == 31000) || (int2 == 200) || (int2 == 1200) )
    {
        boundaryNodePtr = allocateNewBoundaryNodeBlockF();
        boundaryNodePtr->boundaryNodeId = int1;
    }

    fscanf(infile,"%d %d",&int1, &int2);
}

}

/*

```

Appendix B

FEMCONVT Source Code

Listing

```

C THIS PROGRAM CALCULATES THE FLUXES THROUGH THE
C FACES OF A RMA10 BINARY
C OUTPUT FILE. IT ALSO CALCULATES THEIR VOLUME.
Parameter (MNP=2000,MEL=2000,NLAYM=4)
CHARACTER CHFN*15
DIMENSION IDND(MNP,8),NNPE(MEL),LIS(MNP),FLUX(MNP)
,AREA(MNP)
DIMENSION LISE(MEL),VOL(MEL),VAREA(MEL),VFLUX(MEL)
DIMENSION CORD(MNP,3),SPEC(MNP,3),ALFA(MNP),NFIX(MNP)
, AO(MNP),NSURF(MNP),NDEP(MNP),NREF(MNP),NOP(MEL,20)
, NCORN(MEL),IMAT(MEL),TH(MEL),NFIHX(MEL),WIDTH(MNP)
DIMENSION XVEL(4,MNP),VVEL(MNP),DFCT(MEL)

C
C DEFINITIONS
C
C JNN = # OF THE MID-SIDE NODE USED TO NUMBER THE FACE
C NODR = NODE ID FOR RIGHT END TOP
C NODL = NODE ID FOR LEFT END TOP
C NQD = NUMBER OF QUADRILATERALS ALONG THIS FACE
C NTR = NUMBER OF TRIANGLES ALONG THIS FACE
C IDND(I,J) = NODE CONNECTION TABLE AROUND A FACE; WHERE I IS THE
C FACE NUMBER AND J IS THE LOCAL NODE NUMBER
C NNPE(I) = THE NUMBER OF NODES MAKING UP THIS FACE 6 OR 8; I IS
C THE FACE NUMBER
C NES = THE NUMBER OF SURFACE ELEMENTS (I.E. PLANAR)
C JNM = THE NUMBER OF VERTICAL FACES
C LIS(1-JNM)=LIST OF THE VERTICAL FACE NUMBERS
C FLUX(I) = THE FLUX FOR FACE LIS(I)
C VOL(I) = THE VOLUME OF ELEMENT LISE(I)
C LISE(1-JNV) = LIST OF ELEMENTS FOR VOLUMES AND VERTICAL FLUX
C VAREA(I) = THE VERTICAL FLUX OUT OF THE TOP OF ELEMENT I
C
C ELEV IS HARDWIRED TO THIS APPLICATION THIS NEEDS TO BE CHANGED
C TO SOMETHING MORE GENERAL

```


C
C
C

LOOP THROUGH ALL THE 2D SURFACE ELEMENTS IN THE GEOMETRY

```

jnm=0
DO 100 IE=1,NES
  DO 110 I=1,ncorn(ie),2
    JNN = NOP(IE,I+1)
    if(nnpe(jnn).ne.0)go to 110
    JNE = (NDEP(JNN)+1)/2
    NODL=NOP(IE,I)
    IF((I+1).EQ.ncorn(ie))THEN
      NODR=NOP(IE,i-6)
    ELSE
      NODR=NOP(IE,I+2)
    END IF
    NELL = (NDEP(NODL)-1)/2
    NELR = (NDEP(NODR)-1)/2
    nqd=nell
    if(nelr.lt.nqd)nqd=nelr
    ntr=jne-nqd
    IF(NQD.NE.0) THEN
      DO 120 J=1,NQD
        IF(J.EQ.1)THEN
          IDEL = JNN
          jnm=jnm+1
          lis(jnm)=idel
          IDND(IDEL,1) = NODL
          IDND(IDEL,2) = NREF(NODL)+1
          IDND(IDEL,3) = NREF(NODL)+2
          IDND(IDEL,4) = NREF(IDEL)+1
          IDND(IDEL,5) = NREF(NODR)+2
          IDND(IDEL,6) = NREF(NODR)+1
          IDND(IDEL,7) = NODR
          IDND(IDEL,8) = JNN
        
```

```

      NNPE(IDEL) = 8
    ELSE
      IDEL=NREF(JNN)+J-1
      JNM=JNM+1
      LIS(JNM)=IDEL
      IDND(IDEL,1) = NREF(NODL)+(J-1)*2
      IDND(IDEL,2) = IDND(IDEL,1)+1
      IDND(IDEL,3) = IDND(IDEL,2)+1
      IDND(IDEL,4) = IDEL+1
      IDND(IDEL,7) = NREF(NODR)+(J-1)*2
      IDND(IDEL,6) = IDND(IDEL,7)+1
      IDND(IDEL,5) = IDND(IDEL,6)+1
      IDND(IDEL,8) = IDEL
      NNPE(IDEL) = 8
    END IF
  CONTINUE
ENDIF

120
C
  IF(NTR.NE.0)THEN
    DO 130 J=1, NTR
      IF (NQD.EQ.0)THEN
        IF(J.EQ.1)THEN
          IF (NELL.GT.NELR)THEN
            IDEL = JNN
            JNM=JNM+1
            LIS(JNM)=IDEL
            IDND(IDEL,1) = NODL
            IDND(IDEL,2) = NREF(NODL)+1
            IDND(IDEL,3) = NREF(NODL)+2
            IDND(IDEL,4) = NREF(IDEL)+1
            IDND(IDEL,5) = NODR
            IDND(IDEL,6) = IDEL
            NNPE(IDEL) = 6
          ELSE

```

```

IDEL = JNN
JNM=JNM+1
LIS(JNM)=IDEL
IDND(IDEL,1) = NODL
IDND(IDEL,2) = NREF(IDEL)+1
IDND(IDEL,5) = NODR
IDND(IDEL,4) = NREF(NODR)+1
IDND(IDEL,3) = NREF(NODR)+2
IDND(IDEL,6) = IDEL
NNPE(IDEL) = 6
ENDIF
ELSE
IF(NELL.GT.NELR)THEN
IDEL = NREF(JNN) + J - 1
JNM=JNM+1
LIS(JNM)=IDEL
NOPT = NQD+J-1
IDND(IDEL,1) = NREF(NODL)+NOPT*2
IDND(IDEL,2) = IDND(IDEL,1)+1
IDND(IDEL,3) = IDND(IDEL,2)+1
IDND(IDEL,4) = IDEL+1
IDND(IDEL,5) = NODR
IDND(IDEL,6) = IDEL
NNPE(IDEL) = 6
ELSE
IDEL = NREF(JNN) + J - 1
JNM=JNM+1
LIS(JNM)=IDEL
NOPT = NQD+J-1
IDND(IDEL,1) = NODL
IDND(IDEL,2) = IDEL+1
IDND(IDEL,5) = NREF(NODR) + NOPT*2
IDND(IDEL,4) = IDND(IDEL,5)+1
IDND(IDEL,3) = IDND(IDEL,5)+2

```

```

IDND(IDEL,6) = IDEL
NNPE(IDEL) = 6
ENDIF
ELSE
NOPT = NQD+J-1
IDEL = NREF(JNN) + NOPT
JNM=JNM+1
LIS(JNM)=IDEL
IF(NELL.GT.NELR)THEN
IDND(IDEL,1) = NREF(NODL)+NOPT*2
IDND(IDEL,2) = IDND(IDEL,1)+1
IDND(IDEL,3) = IDND(IDEL,2)+1
IDND(IDEL,4) = IDEL+1
IDND(IDEL,5) = NREF(NODR)+NQD*2
IDND(IDEL,6) = IDEL
NNPE(IDEL) = 6
ELSE
IDND(IDEL,1) = NREF(NODL)+NQD*2
IDND(IDEL,2) = IDEL+1
IDND(IDEL,5) = NREF(NODR) + NOPT*2
IDND(IDEL,4) = IDND(IDEL,5)+1
IDND(IDEL,3) = IDND(IDEL,5)+2
IDND(IDEL,6) = IDEL
NNPE(IDEL) = 6
ENDIF
ENDIF
CONTINUE
ENDIF
CONTINUE
CONTINUE
c
c Now calculate fluxes
c

```



```

      read(60,end=200)tet,np,ndf,
      .      ((xvel(k,j),k=1,ndf),vvel(j),j=1,np),
      .      (dfct(j),j=1,ne)

```

C
C
C

THIS IS CURRENTLY SETUP FOR QUADRILATERAL ONLY

```

DO 210 I=1,JNM
  IFACE=LIS(I)
  X1=CORD(IDND(IFACE,1),1)
  Y1=CORD(IDND(IFACE,1),2)
  Z1=CORD(IDND(IFACE,1),3)
  X3=CORD(IDND(IFACE,3),1)
  Y3=CORD(IDND(IFACE,3),2)
  Z3=CORD(IDND(IFACE,3),3)
  X5=CORD(IDND(IFACE,5),1)
  Y5=CORD(IDND(IFACE,5),2)
  Z5=CORD(IDND(IFACE,5),3)
  X7=CORD(IDND(IFACE,7),1)
  Y7=CORD(IDND(IFACE,7),2)
  Z7=CORD(IDND(IFACE,7),3)
  U1=XVEL(1,IDND(IFACE,1))
  V1=XVEL(2,IDND(IFACE,1))
  H1=XVEL(3,IDND(IFACE,1))
  U2=XVEL(1,IDND(IFACE,2))
  V2=XVEL(2,IDND(IFACE,2))
  U3=XVEL(1,IDND(IFACE,3))
  V3=XVEL(2,IDND(IFACE,3))
  H3=XVEL(3,IDND(IFACE,3))
  U4=XVEL(1,IDND(IFACE,4))
  V4=XVEL(2,IDND(IFACE,4))
  U5=XVEL(1,IDND(IFACE,5))
  V5=XVEL(2,IDND(IFACE,5))
  H5=XVEL(3,IDND(IFACE,5))
  U6=XVEL(1,IDND(IFACE,6))

```

```

V6=XVEL(2,IDND(IFACE,6))
U7=XVEL(1,IDND(IFACE,7))
V7=XVEL(2,IDND(IFACE,7))
H7=XVEL(3,IDND(IFACE,7))
U8=XVEL(1,IDND(IFACE,8))
V8=XVEL(2,IDND(IFACE,8))

```

C
C
C

CORRECT THE COORDINATES FOR THE TRANSFORMATION

```

Z1=(Z1-AO(IDND(IFACE,1)))/(ELEV-AO(IDND(IFACE,1)))
*XVEL(3,IDND(IFACE,1))+AO(IDND(IFACE,1))
Z3=(Z3-AO(IDND(IFACE,3)))/(ELEV-AO(IDND(IFACE,3)))
*XVEL(3,IDND(IFACE,3))+AO(IDND(IFACE,3))
Z5=(Z5-AO(IDND(IFACE,5)))/(ELEV-AO(IDND(IFACE,5)))
*XVEL(3,IDND(IFACE,5))+AO(IDND(IFACE,5))
Z7=(Z7-AO(IDND(IFACE,7)))/(ELEV-AO(IDND(IFACE,7)))
*XVEL(3,IDND(IFACE,7))+AO(IDND(IFACE,7))

```

C
C
C
C

CALCULATE HORIZONTAL FLUXES

reference distances to a corner

```

X1 = X1 - X7
Y1 = Y1 - Y7
Z1 = Z1 - Z7
X3 = X3 - X7
Y3 = Y3 - Y7
Z3 = Z3 - Z7
X5 = X5 - X7
Y5 = Y5 - Y7
Z5 = Z5 - Z7

```

C
C

temporary variables for jacobians

```

X1Z1 = X1 * Z1
X3Z1 = X3 * Z1

```

$X5Z1 = X5 * Z1$
 $X1Z3 = X1 * Z3$
 $X3Z3 = X3 * Z3$
 $X5Z3 = X5 * Z3$
 $X1Z5 = X1 * Z5$
 $X3Z5 = X3 * Z5$
 $X5Z5 = X5 * Z5$

C

$Y1Z1 = Y1 * Z1$
 $Y3Z1 = Y3 * Z1$
 $Y5Z1 = Y5 * Z1$
 $Y1Z3 = Y1 * Z3$
 $Y3Z3 = Y3 * Z3$
 $Y5Z3 = Y5 * Z3$
 $Y1Z5 = Y1 * Z5$
 $Y3Z5 = Y3 * Z5$
 $Y5Z5 = Y5 * Z5$

C

$FX = (U1*(-Y1Z3+Y3Z1-2.*Y3Z5+2.*Y5Z3)$
 $+2.*U2*(-4.*Y3Z1+Y5Z1+4.*Y1Z3$
 $-3.*Y5Z3-Y1Z5+3.*Y3Z5)$
 $+U3*(Y3Z1+Y5Z1-Y1Z3+Y5Z3-Y1Z5-Y3Z5)$
 $+2.*U4*(-3.*Y3Z1+Y5Z1+3.*Y1Z3$
 $-4.*Y5Z3-Y1Z5+4.*Y3Z5)$
 $+U5*(-2.*Y1Z3+2.*Y3Z1+Y5Z3-Y3Z5)$
 $+2.*U6*(2.*Y1Z3-2.*Y3Z1-Y5Z1$
 $-3.*Y5Z3+Y1Z5+3.*Y3Z5)$
 $+U7*(-2.*Y1Z3-Y5Z1+Y1Z5+2.*Y3Z1$
 $-2.*Y3Z5+2.*Y5Z3)$
 $+2.*U8*(-3.*Y3Z1-Y5Z1+3.*Y1Z3$
 $+Y1Z5+2.*Y3Z5-2.*Y5Z3))$
 $/36.$

C

```

FY = (V1*(-X1Z3+X3Z1-2.*X3Z5+2.*X5Z3)
+2.*V2*(-4.*X3Z1+X5Z1+4.*X1Z3
-3.*X5Z3-X1Z5+3.*X3Z5)
+V3*(X3Z1+X5Z1-X1Z3+X5Z3-X1Z5-X3Z5)
+2.*V4*(-3.*X3Z1+X5Z1+3.*X1Z3
-4.*X5Z3-X1Z5+4.*X3Z5)
+V5*(-2.*X1Z3+2.*X3Z1+X5Z3-X3Z5)
+2.*V6*(2.*X1Z3-2.*X3Z1-X5Z1
-3.*X5Z3+X1Z5+3.*X3Z5)
+V7*(-2.*X1Z3-X5Z1+X1Z5+2.*X3Z1
-2.*X3Z5+2.*X5Z3)
+2.*V8*(-3.*X3Z1-X5Z1+3.*X1Z3
+X1Z5+2.*X3Z5-2.*X5Z3))
/36.

```

```

FLUX(I) = FX + FY
AX = 0.5*(Y1Z3-Y3Z1+Y3Z5-Y5Z3)
AY = 0.5*(X1Z3-X3Z1+X3Z5-X5Z3)
AREA(I)=SQRT(AX*AX+AY*AY)
if((lis(i).gt.980).and.(lis(i).lt.990))then
WRITE(*,*) 'FX,FY', FX,FY
WRITE(*,*) LIS(I),FLUX(I),AREA(I)
endif

```

```

210 CONTINUE
200 continue

```

```

C
C
C

```

3D ELEMENTS VOLUME CALCULATION

```

JNV = 0
DO 300 IE=1,NE
IF (NCORN(IE).EQ.20)THEN
JNV = JNV+1
LISE(JNV)=IE
IB1=NOP(IE,1)
IB3=NOP(IE,3)

```

```

IB5=NOP(IE,5)
IB7=NOP(IE,7)
IT1=NOP(IE,13)
IT2=NOP(IE,14)
IT3=NOP(IE,15)
IT4=NOP(IE,16)
IT5=NOP(IE,17)
IT6=NOP(IE,18)
IT7=NOP(IE,19)
IT8=NOP(IE,20)
if(ie.eq.569)then
    write(*,*)'ib',ib1,ib3,ib5,ib7
    write(*,*)'it',it1,it3,it5,it7
end if
X1=CORD(IB1,1)
X3=CORD(IB3,1)
X5=CORD(IB5,1)
X7=CORD(IB7,1)
Y1=CORD(IB1,2)
Y3=CORD(IB3,2)
Y5=CORD(IB5,2)
Y7=CORD(IB7,2)
ZB1=CORD(IB1,3)
ZB3=CORD(IB3,3)
ZB5=CORD(IB5,3)
ZB7=CORD(IB7,3)
ZT1=CORD(IT1,3)
ZT3=CORD(IT3,3)
ZT5=CORD(IT5,3)
ZT7=CORD(IT7,3)
ZB1=(ZB1-AO(IB1))/(ELEV-AO(IB1))
    *XVEL(3,IB1)+AO(IB1)
ZB3=(ZB3-AO(IB3))/(ELEV-AO(IB3))

```

```

      *XVEL(3,IB3)+AO(IB3)
ZB5=(ZB5-AO(IB5))/(ELEV-AO(IB5))
      *XVEL(3,IB5)+AO(IB5)
ZB7=(ZB3-AO(IB7))/(ELEV-AO(IB7))
      *XVEL(3,IB7)+AO(IB7)
ZT1=(ZT1-AO(IT1))/(ELEV-AO(IT1))
      *XVEL(3,IT1)+AO(IT1)
ZT3=(ZT3-AO(IT3))/(ELEV-AO(IT3))
      *XVEL(3,IT3)+AO(IT3)
ZT5=(ZT5-AO(IT5))/(ELEV-AO(IT5))
      *XVEL(3,IT5)+AO(IT5)
ZT7=(ZT3-AO(IT7))/(ELEV-AO(IT7))
      *XVEL(3,IT7)+AO(IT7)
X3Y1=X3*Y1
X5Y1=X5*Y1
X7Y1=X7*Y1
X1Y3=X1*Y3
X5Y3=X5*Y3
X7Y3=X7*Y3
X1Y5=X1*Y5
X3Y5=X3*Y5
X7Y5=X7*Y5
X1Y7=X1*Y7
X3Y7=X3*Y7
X5Y7=X5*Y7

```

C
C
C

CALCULATE THE VOLUME OF AN ELEMENT

```

VOL(JNV)=(ZB1-ZT1)*(2.*X3Y1-2.*X7Y1-2.*X1Y3+X5Y3
+X7Y3-X3Y5+X7Y5+2.*X1Y7-X3Y7-X5Y7)/12.
+(ZB3-ZT3)*(2.*X3Y1-X5Y1-X7Y1-2.*X1Y3+
2.*X5Y3+X1Y5-2.*X3Y5+X7Y5+X1Y7-X5Y7)/12.
+(ZB5-ZT5)*(X3Y1-X7Y1-X1Y3+2.*X5Y3-X7Y3
-2.*X3Y5+2.*X7Y5+X1Y7+X3Y7-2.*X5Y7)/12.

```

.
. .
. .
. .
. .

```

      .
      .
      C      +(ZB7-ZT7)*(X3Y1+X5Y1-2.*X7Y1-X1Y3+X5Y3
      C      -X1Y5-X3Y5+2.*X7Y5+2.*X1Y7-2.*X5Y7)/12.
      C

```

CALCULATE THE VERTICAL FLUX AND AREA

```

      W1=VVEL(IT1)
      W2=VVEL(IT2)
      W3=VVEL(IT3)
      W4=VVEL(IT4)
      W5=VVEL(IT5)
      W6=VVEL(IT6)
      W7=VVEL(IT7)
      W8=VVEL(IT8)
      VAREA(INV)=0.5*(-X3Y1+X7Y1+X1Y3-X5Y3-X7Y5-X1Y7
      +X5Y7+X3Y5)
      TMP1=W1*((X3Y1-X7Y1-X1Y3+X5Y3-X3Y5+X7Y5+X1Y7-
      X5Y7)/12.+(-2.*X3Y1+2.*X7Y1+2.*X1Y3-X5Y3-
      X7Y3+X3Y5-X7Y5-2.*X1Y7+X3Y7+X5Y7)/36.)
      TMP2=W2*((4.*X3Y1-X5Y1-3.*X7Y1-4.*X1Y3+3.*X5Y3+
      X7Y3+X1Y5-3.*X3Y5+2.*X7Y5+3.*X1Y7-
      X3Y7-2.*X5Y7)/36.+
      (-4.*X3Y1+X5Y1+3.*X7Y1+4.*X1Y3-3.*X5Y3-
      X7Y3-X1Y5+3.*X3Y5-2.*X7Y5-3.*X1Y7+
      X3Y7+2.*X5Y7)/12.)
      TMP3=W3*((X3Y1-X7Y1-X1Y3+X5Y3-X3Y5+X7Y5+
      X1Y7-X5Y7)/12.+
      (-2.*X3Y1+X5Y1+X7Y1+2.*X1Y3-2.*X5Y3-X1Y5+
      2.*X3Y5-X7Y5-X1Y7+X5Y7)/36.)
      TMP4=W4*((X5Y1-X7Y1-X5Y3+X7Y3-X1Y5+X3Y5+
      X1Y7-X3Y7)/18.+
      (-X3Y1+X7Y1+X1Y3-X5Y3+X3Y5-X7Y5-
      X1Y7+X5Y7)/6.)
      TMP5=W5*((X3Y1-X7Y1-X1Y3+X5Y3-X3Y5+X7Y5+
      X1Y7-X5Y7)/12.+

```

```

      (-X3Y1+X7Y1+X1Y3-2.*X5Y3+X7Y3+2.*X3Y5-
      2.*X7Y5-X1Y7-X3Y7+2.*X5Y7)/36.)
      TMP6=W6*((2.*X3Y1+X5Y1-3.*X7Y1-2.*X1Y3+3.*X5Y3-
      X7Y3-X1Y5-3.*X3Y5+4.*X7Y5+3.*X1Y7+
      X3Y7-4.*X5Y7)/36.+
      (-2.*X3Y1-X5Y1+3.*X7Y1+2.*X1Y3-3.*X5Y3+
      X7Y3+X1Y5+3.*X3Y5-4.*X7Y5-3.*X1Y7-
      X3Y7+4.*X5Y7)/12.)
      TMP7=W7*((X3Y1-X7Y1-X1Y3+X5Y3-X3Y5+X7Y5+
      X1Y7-X5Y7)/12.+
      (-X3Y1-X5Y1+2.*X7Y1+X1Y3-X5Y3+X1Y5+
      X3Y5-2.*X7Y5-2.*X1Y7+2.*X5Y7)/36.)
      TMP8=W8*((-X5Y1+X7Y1+X5Y3-X7Y3+X1Y5-X3Y5-
      X1Y7+X3Y7)/18.+
      (-X3Y1+X7Y1+X1Y3-X5Y3+X3Y5-X7Y5-
      X1Y7+X5Y7)/6.)
      VFLUX(JNV)=TMP1+TMP2+TMP3
      +TMP4+TMP5+TMP6+TMP7+TMP8
      ENDIF
300  CONTINUE
C
C   THE VARIABLES YOU WANT OUT OF THIS ARE

      write(10,5000) JNM
DO I=1,JNM
  J=LIS(I)
  WRITE(10,1000) J,AREA(I),FLUX(I)      ! FACE, AREA OF FACE, FLUX
END DO

      write(10,5000) JNV
DO I=1,JNV
  J=LISE(I)

```



```

WRITE(10,2000) I,VOL(I),VAREA(I),VFLUX(I) ! ELEMENT, VOLUME, AREA
! OF TOP, VERTICAL
! FLUX OUT TOP

END DO

close(10)

5000 format(i8)
1000 format(i8,2x,e15.9,2x,e15.9)
2000 format(i8,2x,e15.9,2x,e15.9,2x,e15.9)

END

```

Appendix C

Modifications to ICM Code

Several modifications were made to the original ICM source code to allow it to be driven by the RMA10 hydrodynamic model. The changes made are detailed below:

Modification 1:

The inline code for reading the map file:

***** Flow mapping data

```

OPEN (MAP,FILE=MAPFN,STATUS='OLD')
READ (MAP,1110) (QD(F),ILB(F),IB(F),JRB(F),F=1,NQF)
READ (MAP,1027) (NVF(SB),SB=1,NSB)
READ (MAP,1100)
DO 10010 SB=1,NSB
  READ (MAP,1130) (VFN(F,SB),F=1,NVF(SB))
10010 CONTINUE
  READ (MAP,1027) (OBP(F),F=1,NOBP)
CLOSE (MAP)

```

was changed and implemented as a subroutine:

```

subroutine readMap(MAPFN)

character*72 MAPFN

include 'model.inc'

integer HHtag(NFEMHHFFP), HVtag(NFEMVFFP), Itag(NQFP),
.   HHtagToltagMap(NFEMHHFFP), HVtagToltagMap(NFEMVFFP),
.   FemCellTolcmCell(NBP)
common /lookup/ HHtag, HVtag, Itag, HHtagToltagMap,
.   HVtagToltagMap, FemCellTolcmCell

```

```

integer F, SB, ISB
integer icmCellId, femCellId

open(MAP,FILE=MAPFN,STATUS='OLD')

read(map,1000)
do b=1,NBP
  read(map,1500) icmCellId, femCellId
  FemCellToIcmCell(femCellId) = icmCellId
enddo

read(map,1000)
read(MAP,2000) (ILB(F),IB(F),JB(F),JRB(F),ITAG(F),F=1,NQF)

read(map,1000)
read(MAP,2010) (NVF(SB),SB=1,NSB)

read(map,1000)
do SB=1,NSB
  READ (MAP,2030) ISB, (VFN(F,SB),F=1,NVF(SB))
enddo

close(MAP)

return

1000 format(/)
1500 format(I8,I8)
2000 format(8X,4I8,15x,I6)
2010 format(8X,I8)
2020 format(/)
2030 format(I8,9I8)

end

```

Modification 2:

The inline code for reading the geo file:

***** Geometric data

```
OPEN (GEO,FILE=GEOFN,STATUS='OLD')
IF (BINARY_HYDRO .OR. DEPTH_AVG_HYDRO) THEN
  READ (GEO,1120) (BU(B),B=1,NB)
  READ (GEO,1140) (SBN(SB),BBN(SB),SB=1,NSB)
ELSE
  READ (GEO,1000)
  READ (GEO,1150) (BL(B,1),BL(B,2),BL(B,3),V1(B),ZD(B),BU(B),
    B=1,NB)
  READ (GEO,1170) (SBN(SB),BBN(SB),SB=1,NSB)
  DO 10015 SB=1,NSB
    SFA(SB) = V1(SBN(SB))/BL(SBN(SB),3)
  10015 CONTINUE
  END IF
  CLOSE (GEO)
```

was changed and implemented as a subroutine:

```
subroutine readGeo(GEOFN)
character*72 GEOFN

include 'model.inc'

integer f,sb

dimension BIL(NHQP), BI(NHQP), BID(NHQP), BIR(NHQP)
common /rma10/ BIL, BI, BID, BIR
```

```

c      Data from map generator
      open (geo,file=GEOFN,status='OLD')

      read(geo,1000)
c      Surface box id
      read(geo,1020) (SBN(SB),BBN(SB),SB=1,NSB)

      read(geo,1040)
c      Upper box for each box
      read(geo,1025) (bu(b),b=1,nb)

      read(geo,1040)
c      Centroid distances
      do f=1,NHQP
        read(geo,1010) BIL(f), BI(f), BID(f), BIR(f)
      enddo

c      NOTE !! following moved
c      to hydro file.
c      Box urface area
      read(geo,1030) (sfa(sb),sb=1,nsb)

      close (geo)

      return

1000 format(1x)
1010 format(4(2x,e11.6))
1020 format(16,17)
1025 format(16)
1030 format(e15.9)
1040 format(/)

      end

```

Modification 3:

The inline code for reading the time-invariant hydro data from the hydro file:

```
***** Time-invariant hydrodynamic data

IF (BINARY_HYDRO) THEN
  READ (HYD) SFA
  READ (HYD) (BL(SB,1),SB=1,NSB)
  READ (HYD) (BL(SB,2),SB=1,NSB)
  READ (HYD) (A(F),F=1,NHQF)
  READ (HYD) HMBV
  READ (HYD) HMSBV
ELSE IF (ASCII_HYDRO) THEN
  READ (HYD,1000)
  READ (HYD,1160) (A(F),F=1,NQF)
  READ (HYD,1100)
ELSE IF (DEPTH_AVG_HYDRO) THEN
  READ (HYD) SFA
  READ (HYD) (A(F),F=1,NHQF)
  READ (HYD) (BL(SB,1),SB=1,NSB)
  READ (HYD) (BL(SB,2),SB=1,NSB)
  READ (HYD) HMSBV
ELSE
  WRITE(*,*) 'hydro file specified incorrectly'
  STOP
ENDIF
```

was changed and implemented as a subroutine:

```
logical function initializeHydro()
include 'model.inc'
```

```

integer HHtag(NFEMHHFFP), HVtag(NFEMVFFP), Itag(NQFP),
.   HHtagToltagMap(NFEMHHFFP), HVtagToltagMap(NFEMVFFP),
.   FemCellTolcmCell(NBP)

common /lookup/ HHtag, HVtag, Itag, HHtagToltagMap,
.   HVtagToltagMap, FemCellTolcmCell

integer HYD2
common /lookup2/ HYD2

integer node_id, hface_id, vface_id, box_id
real f_area, flux, volume, top_area, v_flux

integer i, f1, f2, b1

integer nHHtags1, nHVTags2, HHtagValue, HVtagValue,
.   ItagIndex

integer unusedHFaceCount, unusedVFaceCount

logical end_of_file, readHydro

c   face_id: id of flow face
c   f_area: Flow face area
c   flux: Flow face flux
c   box_id: id of box
c   volume: box volume
c   top_area: area of box top
c   v_flux: flux out of boxes top face

c   Clear the following arrays
do i=1,NFEMHHFFP
  HHtagToltagMap(i) = 0

```



```

        enddo
        do i=1,NFEMVFFP
            HVtagToItagMap(i) = 0
        enddo

        open(HYD2,FILE=HYDFN(1),STATUS='OLD',FORM = 'FORMATTED')

        initializeHydro = .TRUE.

c          Read in horizontal flow face
c          data from rma10 output file

        read(hyd2,100,end=50) nHHtags1

        f2 = 0
        do f1=1,nHHtags1
            read(hyd2,200,end=50) node_id, f_area, flux
            f2 = f2 + 1
            HHtag(f2) = node_id
        enddo

        unusedHFaceCount = 0

        do i = 1, f2

            HHtagValue = HHtag(i)
            ItagIndex = 0
            j = 0

20      continue

```

```

j = j + 1
if(j .gt. NHQP) goto 30

if(Itag(j) .eq. HhtagValue) then
  ItagIndex = j
  goto 30
else
  goto 20
endif

30  continue

c      If HtagToItagMap(HtagValue) = 0 then
c      not a "flow face" we are interested in!

      HhtagToItagMap(i) = ItagIndex
      if(ItagIndex .eq. 0) unusedHFaceCount = unusedHFaceCount+1

      enddo

c      Read in cell data and vertical
c      flow face data
      read(hyd2,100,end=50) nHVtags2

      f2 = 0
      do b1=1,nHVtags2
        read(hyd2,300) box_id, volume, top_area, v_flux
        f2 = f2 + 1
        HVtag(f2) = box_id
      enddo

      close(HYD2)

```

```

unusedVFaceCount = 0

do i = 1, f2
    HVtagValue = HVtag(i)
    ItagIndex = 0
    j = NHQP-1

    2000 continue

    j = j + 1
    if(j .gt. NQFP) goto 3000

    if(Itag(j) .eq. HVtagValue) then
        ItagIndex = j
        goto 3000
    else
        if(-Itag(j) .eq. HVtagValue) then
            ItagIndex = -j
        else
            goto 2000
        endif
    endif

    3000 continue

    c      If HtagToItagMap(HtagValue) = 0 then
    c      not a "flow face" we are interested in!

    HVtagToItagMap(HVtagValue) = ItagIndex
    if(ItagIndex .eq. 0) unusedVFaceCount = unusedVFaceCount+1

enddo

```

```

write(*,*) ' finished tag mapping'

close(HYD2)

c
c      Need to initialize HMV (Hydrodynamic
c      model cell volume) array and A (ICM flow
c      face area) array. Only way to do this is
c      to read data in from hydro file.

open(HYD,FILE=HYDFN(1),STATUS='OLD',FORM = 'FORMATTED')

end_of_file = readHydro()
if(end_of_file) then
  initializeHydro = .TRUE.
else
  initializeHydro = .FALSE.
endif

close(2)

return

50 close(HYD)

return

100 format(i8)
200 format(18,2x,e15.9,2x,e15.9)
300 format(18,2x,e15.9,2x,e15.9,2x,e15.9)

end

```

Modification 4:

A subroutine for reading the time-variant hydro data was written to read the RMA10 hydro output data. This routine replaces ICM's HYDRO subroutine. New subroutine code follows:

```

logical function readHydro()
include 'model.inc'

integer  HHtag(NFEMHHFFP), HVtag(NFEMVFFP), Itag(NQFP),
        . HHtagToIcmCell(NFEMHHFFP), HVtagToIcmCell(NFEMVFFP),
        . FemCellToIcmCell(NBP)

common  /lookup/ HHtag, HVtag, Itag, HHtagToIcmCell,
        . HVtagToIcmCell, FemCellToIcmCell

logical firstHR
common  /lookup3/firstHR
logical end_of_file
integer node_id, hface_id, vface_id, box_id
real    f_area, flux, volume, top_area, v_flux
integer unusedHFaceCount, unusedVFaceCount
real    sense
integer icm_box_id, fem_box_id
integer f
logical bTagMap

c      NOTE the PARAMETER NFEMFFP MEANS ...
c      Number of Finite Element Model Flow
c      Faces Parameter
c      NFEMFFP = nHtags1 + nHtags2

c      face_id: id of flow face
c      f_area: Flow face area

```

```

c      flux: Flow face flux
c      icm_box_id: id of box in ICM
c      fem_box_id: id of box in RMA0
c      volume: box volume
c      top_area: area of box top
c      v_flux: flux out of boxes top face

      readHydro = .FALSE.

c      Read in horizontal flow face
c      data from rma10 output file

      unusedHFaceCount = 0
      read(hyd,100,end=50) nHtags1
      do f=1,nHtags1

        read(hyd,200,end=50) node_id, f_area, flux

        hface_id = HHtagToItagMap(f)

        if(hface_id.eq. 0) then
          unusedHFaceCount = unusedHFaceCount + 1
        else
          a(hface_id) = f_area
          q(hface_id) = flux
        endif
      enddo

c      Read in cell data and vertical
c      flow face data

      unusedVFaceCount = 0
      read(hyd,100,end=50) nHtags2

```

```

do b=1,nHtags2
  read(hyd,300) fem_box_id, volume, top_area, v_flux
  icm_box_id = FemCellToIcmCell(fem_box_id)
  hmv(icm_box_id) = volume
  bl3(icm_box_id) = volume/top_area
  sfa(icm_box_id) = top_area
  vface_id = HVtagToIcmCell(fem_box_id)
  if(vface_id .eq. 0) then
    unusedVFaceCount = unusedVFaceCount + 1
  else
    q(vface_id) = v_flux
    a(vface_id) = top_area
  endif
enddo
return

50  readHydro = .TRUE.
    return

100 format(i8)
200 format(18,2x,e15.9,2x,e15.9)
300 format(18,2x,e15.9,2x,e15.9,2x,e15.9)

end

```

Modification 5:

The BL array was originally implemented as a two-dimensional array: BL(NUMBER_OF_BOXES,3). This array holds the three lengths (width, length and height) for each cell. The finite-element version does not distinguish between the horizontal distances; therefore this array was replaced with the array BL3(NUMBER_OF_BOXES). This array contains the cell height. All original code references were changed to reflect this modification.

Modification 6:

The mainline initialization of the HMF and V1 arrays:

```
***** Initialize volumes

DO 10110 SB=1,NSB
DO 10100 F=1,NVF(SB)
  HMF(JB(VFN(F,SB))) = HMF(SB)
  V1(JB(VFN(F,SB))) = HMF(SB)
10100 CONTINUE
  HMF(JB(VFN(NVF(SB),SB))) = HMF(SB)
  V1(JB(VFN(NVF(SB),SB))) = HMF(SB)
10110 CONTINUE
```

was replaced with the following code:

```
***** Initialize volumes

do 10100 b=1,NBP
  v1(b) = hmf(b)
10100 continue
```

The FEM version of ICM reads in from the hydrodynamic input file the volume of each box and assigns it directly to the array HMF. There is no intermediate assignment to HMF (volume of boxes below surface layer with the index being the surface box id) or to HMF (volume of boxes in surface layer).

Modification 7:

The mainline initialization of the BL array was eliminated:

***** Initialize box lengths

```
DO 10130 SB=1,NSB
  CDIR$ VECTOR
  DO 10120 F=1,NVF(SB)
    BL(IB(VFN(F,SB)),1) = BL(JB(VFN(NVF(SB),SB)),1)
    BL(IB(VFN(F,SB)),2) = BL(JB(VFN(NVF(SB),SB)),2)
    BL(IB(VFN(F,SB)),3) = HMV(IB(VFN(F,SB)))/SFA(SB)
  10120 CONTINUE
  BL(JB(VFN(NVF(SB),SB)),3) = HMV(JB(VFN(NVF(SB),SB)))/SFA(SB)
  10130 CONTINUE
```

The Bl array was replaced with the BL3 array. The BL3 array is assigned by the subroutine READHYDRO and updated by the subroutine UPDATE.

Modification 8:

Subroutine calls made to HYDRO changed to calls of HYDRO2. The original subroutine HYDRO was not modified. Instead, a new routine specific to RMA10 was written. This new routine handles the hydrodynamic data updates.

```
SUBROUTINE HYDRO2 (NXHYD)
```

```
SAVE
```

```
INCLUDE 'model.inc'
```

```
REAL NXDAY
INTEGER F, SB
LOGICAL END_OF_FILE, readHydro
DIMENSION MASS(0:NBPN,NCP)
```

```

***** Binary time-varying hydrodynamic data

10000 IF (NWQMR.GE.NHMR) THEN

    *****
    *****
    *****
    Hydrodynamic column volumes, flows,
    and vertical diffusions

    end_of_file = readHydro()

10020 IF (END_OF_FILE) THEN

    *****
    Open next hydrodynamic file

    HYDPTR = HYDPTR+1
    IF (DIAGNOSTICS) WRITE (DIA,*) 'Opening hydrodynamic ',
        'file ',HYDPTR,' at day ',
        JDAY
    CLOSE (HYD)
    OPEN (HYD,FILE=HYDFN(HYDPTR),FORM='UNFORMATTED',
        STATUS='OLD')

    end_of_file = readHydro()

    NWQMR = 0
    NHMR = 0

    *****
    Reinitialize HM and WQM volumes

    do b=1,NBP
        v2(b) = hmv(b)
    enddo

    IF (CONSERVE_MASS) THEN

```

```

DO 10047 B=1,NB
DO 10045 JC=1,NAC
  MASS(B,AC(JC)) = C1(B,AC(JC))*V1(B)
  CONTINUE
10045  V1(B) = V2(B)
      V1S(B) = V1(B)
DO 10046 JC=1,NAC
  C1(B,AC(JC)) = MASS(B,AC(JC))/V1(B)
  C2(B,AC(JC)) = MAX(C1(B,AC(JC)),0.0)
  CONTINUE
10046  CONTINUE
10047  CONTINUE
      ELSE
DO 10048 B=1,NB
  V1(B) = V2(B)
  CONTINUE
10048  END IF

```

Reinitialize initial water column mass

IF (MASS_BALANCE) THEN

Reinitialize mass balance variables

```

S1FLXN = 0.
S1FLXP = 0.
S1FLXC = 0.
S2FLXN = 0.
S2FLXP = 0.
S2FLXC = 0.
ATMFLXN = 0.
ATMFLXP = 0.
BENFLXPN = 0.
BENFLXDN = 0.
BENFLXPP = 0.

```

```

BENFLXDP = 0.
BENFLXPC = 0.
DLWCKMN = 0.
DLWCKMC = 0.
BNDFLXN = 0.
BNDFLXP = 0.
BNDFLXC = 0.
BURIALFLXN = 0.
BURIALFLXP = 0.
BURIALFLXC = 0.
DLSedKN = 0.
DLSedKC = 0.
ISED MN = 0.
ISED MP = 0.
ISED MC = 0.

```

```

*****
*****

```

Reinitialize initial water column and
sediment masses

```

DO 10051 J=1,NAC
  JC = AC(J)
  CMass(JC) = 0.0
DO 10050 B=1,NB
  CMass(JC) = CMass(JC)+C1(B,JC)*V1(B)/1000.
  CONTINUE
CONTINUE
IWC MN = ANCC*CMass(4)+ANCD*CMass(5)+ANCG*CMass(6)
      +CMass(10)+CMass(11)+CMass(12)+CMass(13)
      +CMass(14)
IWC MP = CMass(15)+CMass(16)+CMass(17)+CMass(18)
IWC MC = CMass(4)+CMass(5)+CMass(6)+CMass(7)+CMass(8)
      +CMass(9)
IWC MS = ASCD*CMass(5)+CMass(21)+CMass(22)
DO 10058 BB=1,NBB

```

```

ISEDMN = ISEDMN+(CPON(BB,1)+CPON(BB,2)+CPON(BB,3)
      +CNH4(BB)+CNO3(BB))*A(VFN(1,BB))
      *HSED(BB)/1.E6
ISEDMP = ISEDMP+(CPOP(BB,1)+CPOP(BB,2)+CPOP(BB,3)
      +CPIP(BB))*A(VFN(1,BB))*HSED(BB)/1.E6
ISEDMC = ISEDMC+(CPOC(BB,1)+CPOC(BB,2)+CPOC(BB,3))
      *A(VFN(1,BB))*HSED(BB)/1.E6
10058      CONTINUE
      END IF

      END_OF_FILE = .FALSE.

      ELSE

      *****      Reinitialize HM and WQM volumes

      do b=1,NBP
      v2(b) = hmv(b)
      enddo

      NHMR = NHMR+1

      END IF

      GO TO 10000
      END IF
      NWQMR = NWQMR+1
      NXHYD = NXHYD+INT(AHMDLT)

```

***** Calculations

***** Dead sea case

```

IF (.NOT.FLOW) THEN
DO 10100 F=1,NQF
  Q(F) = 0.0
10100 CONTINUE
END IF
IF (.NOT.XY_DIFFUSION) THEN
DO 10110 F=1,NHQF
  DIFF(F) = 0.
10110 CONTINUE
END IF

IF (.NOT.Z_DIFFUSION) THEN
DO 10120 F=NHQF+1,NQF
  DIFF(F) = 0.
10120 CONTINUE
END IF

***** Determine flow direction

DO 10130 F=1,NQF
IF (Q(F).GE.0.0) THEN
  POSITIVE_FLOW(F) = .TRUE.
ELSE
  POSITIVE_FLOW(F) = .FALSE.
END IF
10130 CONTINUE

***** Adjust vertical diffusion

DO 10140 F=NHQF+1,NQF
  DIFF(F) = ZDFMUL*DIFF(F)
10140 CONTINUE

```

***** ASCII input FORMAT statements

```
1000 FORMAT(21X,E10.3,5X,E10.3)
1005 FORMAT(F8.0)
1010 FORMAT(///)
1020 FORMAT(13X,F13.0)
1030 FORMAT(/)
```

END

Modification 9:

The following mainline code for updating the geometry variables:

***** Update WQM volumes

```
DO 10600 F=1,NQF
```

```
    V2(JB(F)) = V2(JB(F))+Q(F)*DLT
    V2(IB(F)) = V2(IB(F))-Q(F)*DLT
```

```
10600 CONTINUE
```

***** Update box lengths

```
DO 10620 SB=1,NSB
DO 10610 F=1,NVF(SB)
    BL(IB(VFN(F,SB)),3) = V2(IB(VFN(F,SB)))/SFA(SB)
10610 CONTINUE
    BL(JB(VFN(NVF(SB),SB)),3) = V2(JB(VFN(NVF(SB),SB)))/SFA(SB)
10620 CONTINUE
```

***** Update layer depths

```
DO 10630 B=1,NB
  ZD(B) = 0.0
10630  CONTINUE
DO 10650 SB=1,NSB
  CDIR$ VECTOR
    DO 10640 F=NVF(SB),1,-1
      ZD(IB(VFN(F,SB))) = ZD(JB(VFN(F,SB)))
        +BL(JB(VFN(F,SB)),3)
10640  CONTINUE
10650  CONTINUE
```

ELSE IF (DEPTH_AVG_HYDRO) THEN

***** Update WQM volumes

```
DO 50600 F=1,NQF

  V2(JB(F)) = V2(JB(F))+Q(F)*DLT
  V2(IB(F)) = V2(IB(F))-Q(F)*DLT
```

50600 CONTINUE

***** Update box lengths

```
DO 50620 SB=1,NSB
  BL(SB,3) = V2(SB) / SFA(SB)
50620  CONTINUE
END IF
```

was replaced with a call to the new subroutine UPDATE:

subroutine updateG(HYDC)


```

character*8 HYDC
integer f, sb

include 'model.inc'
integer f, b, sb

c
c      Check type of hydrodynamics
      if(HYDC.EQ.' BINARY') goto 10
      if(HYDC.EQ.'DEPTH_AV') goto 20
      if(HYDC.EQ.'RMAHYDRO') goto 30

c      BINARY_HYDRO
10 continue

c      Update WQM volumes
      do f=1,NQF
        V2(JB(f)) = V2(JB(f))+Q(f)*DLT
        V2(IB(f)) = V2(IB(f))-Q(f)*DLT
      enddo

c
c      Update box lengths..Note that
c      vertical box length changes
c      every time step because box
c      volume is changing every time
c      step!

      do b=1,nb
        bl3(b) = v2(b)/sfa(b)
      enddo

c      Update layer depths

c      ZD(i) is depth below surface
c      of top of box i!
c      cell depth below equals
c      cell depth above + thickness

```

c of cell above

```

do b=1,NB
  ZD(b) = 0.0
enddo

do sb=1,NSB
  do f=NVF(sb),1,-1
    ZD(IB(VFN(f,sb))) = ZD(JB(VFN(f,sb)))
    +BL3(JB(VFN(f,sb)))
  enddo
enddo

return

```

DEPTH_AVG_HYDRO

c 20 continue

Set depth to box top

```

c
do b=1,NB
  ZD(b) = 0.0
enddo

```

Update WQM volumes

```

c
do f=1,NQF
  V2(JB(f)) = V2(JB(f))+Q(f)*DLT
  V2(IB(f)) = V2(IB(f))-Q(f)*DLT
enddo

```

Update box lengths

c return

RMA10_HYDRO

c

```

30 continue
c
      Update WQM volumes
      do f=1,NQF
        V2(JB(f)) = V2(JB(f))+Q(f)*DLT
        V2(IB(f)) = V2(IB(f))-Q(f)*DLT
      enddo

c
      Update box lengths
      do b=1,nb
        bl3(b) = v2(b)/sfa(b)
      enddo

c
      Set depth to top of box
      do b=1,NB
        ZD(b) = 0.0
      enddo

      do sb=1,NSB
        do f=NVF(sb),1,-1
          ZD(IB(VFN(f,sb))) = ZD(JB(VFN(f,sb)))
            +BL3(JB(VFN(f,sb)))
        enddo
      enddo

      return
      end

```

Modification 10:

This modification concerned replacing the direction dependent algorithm for calculating the advection and diffusion multipliers with one using the centroid parameters. The following mainline code is the original algorithm:

***** Horizontal advection and diffusion multipliers

CDIRS VECTOR

DO 10190 F=1,NHQF

***** Positive flows

```

IF (LEFTM1_BOUNDARY(F)) BL(ILB(F),QD(F)) = BL(IB(F),QD(F))
IF (LEFT_FLOWB(F)) THEN
  BL(IB(F),QD(F)) = BL(JB(F),QD(F))
  BL(ILB(F),QD(F)) = BL(JB(F),QD(F))
END IF
IF (RIGHT_FLOWB(F)) BL(JB(F),QD(F)) = BL(IB(F),QD(F))
SF1(F) = MIN(BL(IB(F),QD(F)),BL(JB(F),QD(F)))
SF2(F,1) = BL(IB(F),QD(F))**2
DEN1(F,1) = 0.25*(BL(ILB(F),QD(F))+2.*BL(IB(F),QD(F))
+BL(JB(F),QD(F)))*(BL(ILB(F),QD(F))
+BL(IB(F),QD(F)))
DEN2(F,1) = -0.25*(BL(IB(F),QD(F))+BL(JB(F),QD(F)))
*(BL(ILB(F),QD(F))+BL(IB(F),QD(F)))
DEN3(F,1) = 0.25*(BL(IB(F),QD(F))+BL(JB(F),QD(F))
*(BL(ILB(F),QD(F))+2.0*BL(IB(F),QD(F))
+BL(JB(F),QD(F)))
T2(F,1) = BL(JB(F),QD(F))/(BL(IB(F),QD(F))+BL(JB(F),QD(F)))
T3(F) = BL(IB(F),QD(F))/(BL(ILB(F),QD(F))+BL(JB(F),QD(F)))
TP1(F,1) = 0.5*(BL(IB(F),QD(F))-BL(JB(F),QD(F)))*SF1(F)
TP2(F,1) = 0.5*(BL(ILB(F),QD(F))+2.0*BL(IB(F),QD(F))
-BL(JB(F),QD(F)))*SF1(F)
TP3(F,1) = 0.5*(BL(ILB(F),QD(F))+3.0*BL(IB(F),QD(F)))*SF1(F)

```

***** Negative flows

```

IF (LEFT_FLOWB(F)) BL(IB(F),QD(F)) = BL(JB(F),QD(F))
IF (RIGHT_FLOWB(F)) THEN

```

```

      BL(JB(F),QD(F)) = BL(IB(F),QD(F))
      BL(JRB(F),QD(F)) = BL(IB(F),QD(F))
      END IF
      IF (RIGHTP1_BOUNDARY(F)) BL(JRB(F),QD(F)) = BL(JB(F),QD(F))
      SF1(F) = MIN(BL(IB(F),QD(F)),BL(JB(F),QD(F)))
      SF2(F,2) = BL(JB(F),QD(F))**2
      DEN1(F,2) = 0.25*(BL(IB(F),QD(F))+2.0*BL(JB(F),QD(F))
      +BL(JRB(F),QD(F)))*(BL(IB(F),QD(F))+BL(JB(F),QD(F)))
      DEN2(F,2) = -0.25*(BL(JB(F),QD(F))+BL(JRB(F),QD(F)))
      * (BL(IB(F),QD(F))+BL(JB(F),QD(F)))
      DEN3(F,2) = 0.25*(BL(IB(F),QD(F))+2.0*BL(JB(F),QD(F))
      +BL(JRB(F),QD(F)))*(BL(JB(F),QD(F))
      +BL(JRB(F),QD(F)))
      T1(F) = BL(JB(F),QD(F))/(BL(IB(F),QD(F))+BL(JB(F),QD(F)))
      T2(F,2) = BL(JB(F),QD(F))/(BL(IB(F),QD(F))+BL(JB(F),QD(F)))
      TP1(F,2) = -0.5*(3.0*BL(JB(F),QD(F))+BL(JRB(F),QD(F)))*SF1(F)
      TP2(F,2) = 0.5*(BL(IB(F),QD(F))-2.0*BL(JB(F),QD(F))
      -BL(JRB(F),QD(F)))*SF1(F)
      TP3(F,2) = 0.5*(BL(IB(F),QD(F))-BL(JB(F),QD(F)))*SF1(F)
      10190 CONTINUE

```

The above code was replaced with the following centroid parameter based algorithm:

```

DO 10195 F=1,NHQF

```

***** Positive flows

```

      IF (LEFTM1_BOUNDARY(F)) BIL(F) = BI(F)
      IF (LEFT_FLOWB(F)) THEN
        BI(F) = 2.0*BID(F)
        BIL(F) = BI(F)
      END IF
      IF (RIGHT_FLOWB(F)) THEN

```

```

BI(F) = 2.0*BID(F)
BIR(F) = BI(F)
END IF
SF1(F) = BI(F)
SF2(F,1) = BI(F)**2
DEN1(F,1) = (BIL(F)+BI(F))*BIL(F)
DEN2(F,1) = -BI(F)*BIL(F)
DEN3(F,1) = BI(F)*(BIL(F)+BI(F))
T2(F,1) = (BI(F)-BID(F))/BI(F)
T3(F) = BID(F)/BI(F)
TP1(F,1) = (2.0*BID(F)-BI(F))*SF1(F)
TP2(F,1) = (2.0*BID(F)-BI(F)+BIL(F))*SF1(F)
TP3(F,1) = (BIL(F)+2.0*BID(F))*SF1(F)

***** Negative flows

IF (LEFT_FLOWB(F)) BI(F) = 2.0*BID(F)
IF (RIGHT_FLOWB(F)) THEN
  BI(F) = 2.0*BID(F)
  BIR(F) = BI(F)
END IF
IF (RIGHTP1_BOUNDARY(F)) BIR(F) = BI(F)
SF1(F) = BI(F)
SF2(F,2) = BI(F)**2
DEN1(F,2) = (BI(F)+BIR(F))*BI(F)
DEN2(F,2) = -BI(F)*BIR(F)
DEN3(F,2) = (BI(F)+BIR(F))*BIR(F)
T1(F) = (BI(F)-BID(F))/BI(F)
T2(F,2) = BID(F)/BI(F)
TP1(F,2) = -(2.0*(BI(F)-BID(F))+BIR(F))*SF1(F)
TP2(F,2) = (2.0*BID(F)-BI(F)-BIR(F))*SF1(F)
TP3(F,2) = (2.0*BID(F)-BI(F))*SF1(F)

```

10195 CONTINUE

Appendix D

MAPPER Input and Output Files for Example Grid

This appendix presents an example grid and the associated input and output files for MAPPER.C. The example consists of a 3 by 2 by 2 grid domain of 12.0 m^3 , with element dimensions 1.0 by 1.0 by 1.0 m. The node numbers are shown at the corners and facial mid-points, and the element numbers are indicated in the center of each element in Figure D1. Plan views are shown in Figure D1 for the two layers at the top, middle, and bottom of each layer. The node-element connectivity output file from RC4IC10.f is shown for the example grid in Table D1. This file provides the input required for MAPPER.C. The output files from MAPPER.C, MAP and GEO, are shown for the example grid in Tables D2 and D3, respectively. Following is a description of the steps to conduct this example, along with explanations for the input and output files.

MAPPER Input File Description

The hydrodynamic grid is initially generated by the FastTABS program, which is a preprocessor and postprocessor for two-dimensional (2-D) finite element models maintained by the U.S. Army Engineer Waterways Experiment Station Coastal and Hydarulics Laboratory. The user interactively constructs a grid within FastTABS that then outputs a mesh geometry file for later input into RMA. All information contained in this file is subsequently written by RMA to what is referred to as the RMA binary output file. This RMA output file ultimately will contain a complete geometric description of the grid in 3-D along with the time-varying hydrodynamic flow fields. The RC4IC10.f postprocessing program reads the RMA binary output file and creates the node-element connectivity file, which is the input file for MAPPER.C

The node-element connectivity file (i.e., Table D1) is described as follows. Information in the first section of this file describes the 2-D mesh geometry of the grid. Each line begins with a line type code consisting of two or three letters. Code definitions follow below.

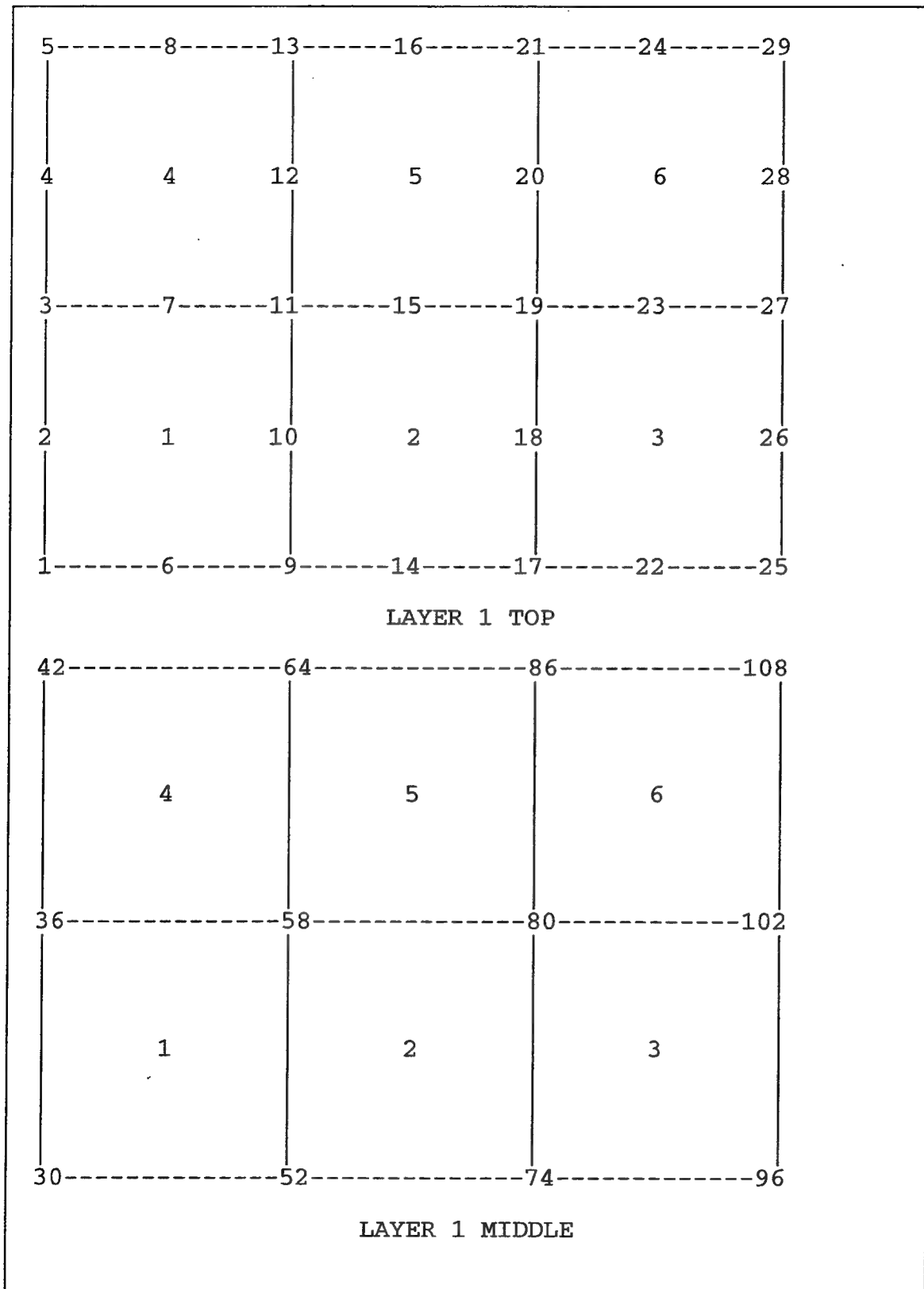


Figure D1. Plan view of example 3 by 1 by 2 grid (Sheet 1 of 3)

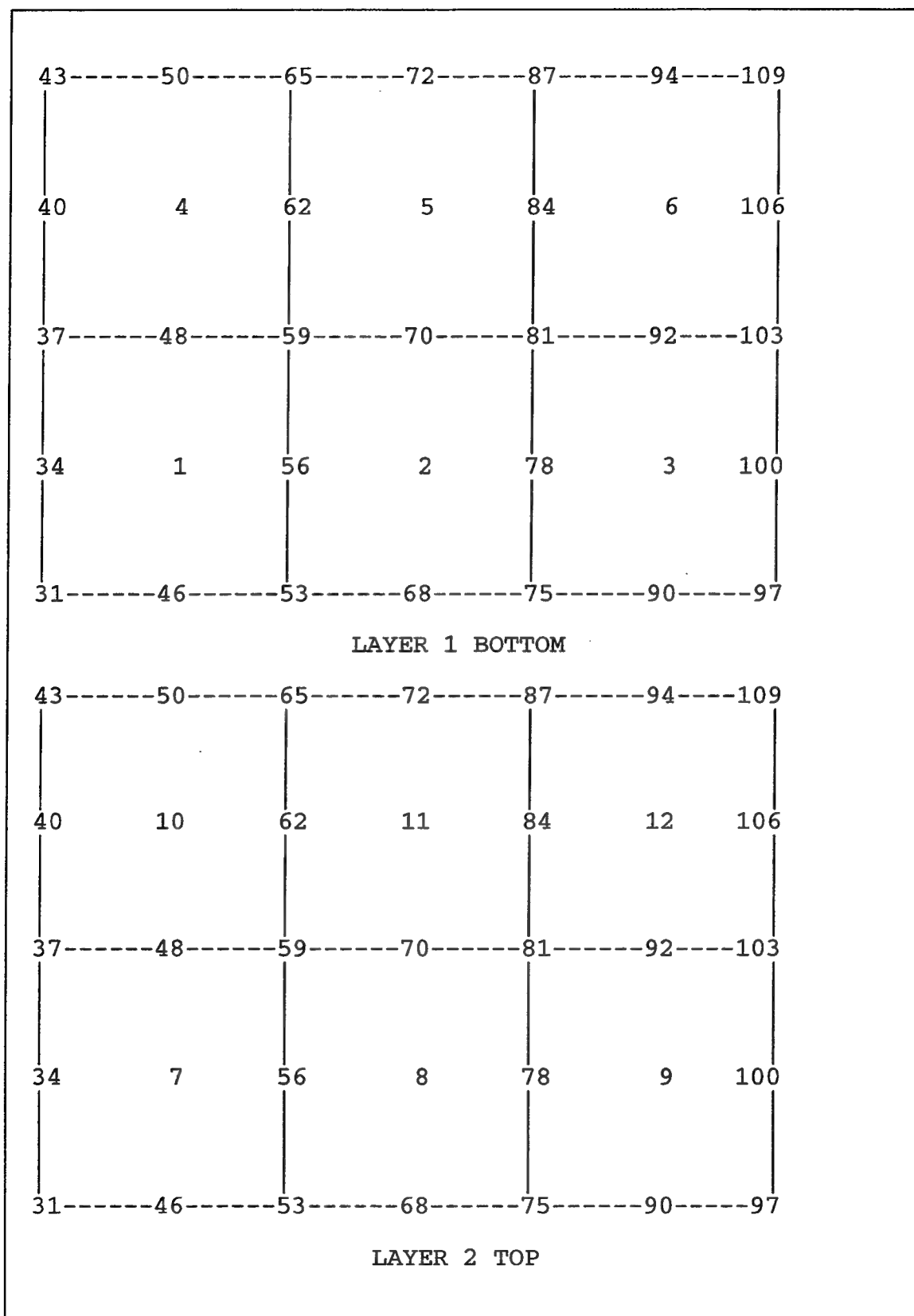


Figure D1. (Sheet 2 of 3)

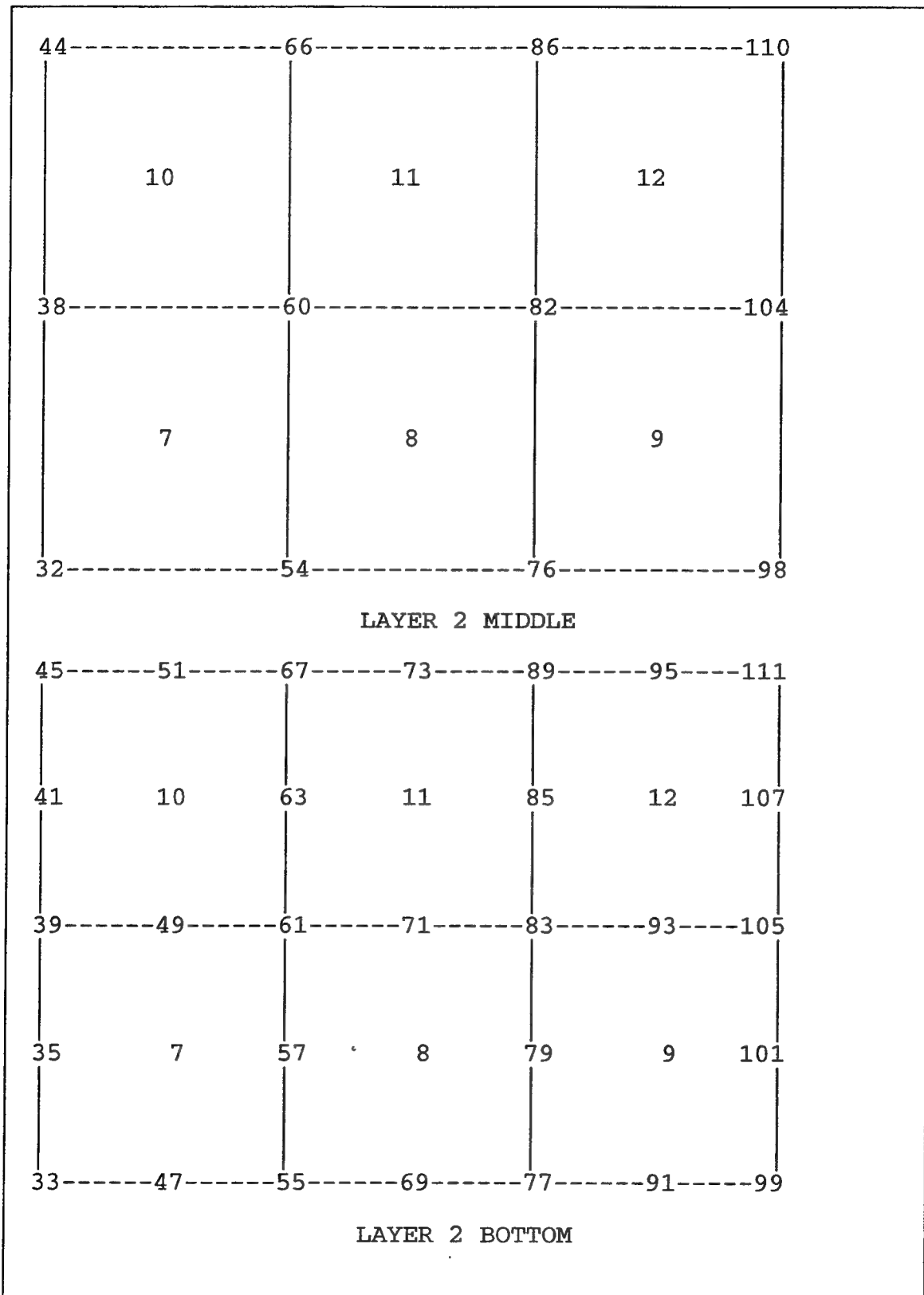


Figure D1. (Sheet 3 of 3)

Table D.1. Node-Element Connectivity File for Example Grid from RC4IC10.f Output File

T1 Example node-element connectivity description file

```

T2
T3
SI 0
$L 3 0 6 0
GO 1 2 3 4 5 -1

GE 1 1 6
GE 4 3 7
GE 2 9 14
GE 5 11 15
GE 3 17 22
GE 6 19 23
GNN 1 1.0
GNN 3 1.0
GNN 5 1.0
GNN 9 2.0
GNN 11 2.0
GNN 13 2.0
GNN 17 3.0
GNN 19 3.0
GNN 21 3.0
GNN 25 4.0
GNN 27 4.0
GNN 29 4.0
VALUES FROM 3D BINARY GEOMETRY FILE (generated by ricr10.f)
NP NE NPM NEM
111 12 29 12

```

```

10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
17 18 19 20 21 22 23 24 25 26 27 28 29 30
18 19 20 21 22 23 24 25 26 27 28 29 30
19 20 21 22 23 24 25 26 27 28 29 30
20 21 22 23 24 25 26 27 28 29 30
21 22 23 24 25 26 27 28 29 30
22 23 24 25 26 27 28 29 30
23 24 25 26 27 28 29 30
24 25 26 27 28 29 30
25 26 27 28 29 30
26 27 28 29 30
27 28 29 30
28 29 30
29 30
30

```

```

SURFACE
NODE NDEP NREF
1 5 29

```

```

2 3 4 5 6 7 8 9
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
3 5 3 5 3 5 3 5 3 5 3 5 3 5 3 5 3 5 3 5 3 5 3 5 3 5
34 35 39 41 45 47 49 52 55 57 61 63 67 69 71 73 77 79 83 85 89 91 93 96 99
102 105 108

```

```

NODE  NSURF
1      1200
30     1200
31     1200
32     1200
33     1200

```

! 1200 means head boundary strip

2	1200
34	1200
35	1200
3	1200
36	1200
37	1200
38	1200
39	1200
4	1200
40	1200
41	1200
5	1200
42	1200
43	1200
44	1200
45	1200
6	1000
46	1000
47	1000
7	0
48	0
49	0
8	1000
50	1000
51	1000
9	1000
52	1000
53	1000
54	1000

! 1000 means wall Boundary strip

! 0 means internal strip

55	1000
10	0
56	0
57	0
11	0
58	0
59	0
60	0
61	0
12	0
62	0
63	0
13	1000
64	1000
65	1000
66	1000
67	1000
14	1000
68	1000
69	1000
15	0
70	0
71	0
16	1000
72	1000
73	1000
17	1000
74	1000

25	1200
96	1200
97	1200
98	1200
99	1200
26	1200
100	1200
101	1200
27	1200
102	1200
103	1200
104	1200
105	1200
28	1200
106	1200
107	1200
29	1200
108	1200
109	1200
110	1200
111	1200

Table D.2. MAP File Generated for Example Grid

ICM	FEM	FFID	ILB	IB	JB	JBR	TYPE	ORIENT	TAG	LAYER
1	1	1	2	1	0	0	B	H	1	1
2	2	2	0	1	2	3	I	H	2	1
3	3	3	0	1	4	0	I	H	3	1
4	4	4	1	2	3	0	I	H	4	1
5	5	5	0	2	5	0	I	H	5	1
6	6	6	2	3	0	0	B	H	6	1
7	7	7	0	3	6	0	I	H	7	1
8	8	8	0	4	0	0	B	H	8	1
9	9	9	5	4	5	6	I	H	9	1
10	10	10	0	5	6	0	I	H	10	1
11	11	11	4	6	0	0	B	H	11	1
12	12	12	5	7	8	0	B	H	12	1
			8	7	0	0	I	H	13	2
			0	7	8	9	I	H	14	2
			0	8	9	0	I	H	15	2
			7	8	11	0	I	H	16	2
			0	9	0	0	B	H	17	2
			8	9	0	0	I	H	18	2
			0	10	0	0	B	H	19	2
			11	10	0	0	I	H		

20	0	10	11	12	I	H	20	2
21	10	11	12	0	I	H	21	2
22	11	12	0	0	B	H	22	2
23	0	7	1	0	I	V	23	2-1
24	0	8	2	0	I	V	24	2-1
25	0	9	3	0	I	V	25	2-1
26	0	10	4	0	I	V	26	2-1
27	0	11	5	0	I	V	26	2-1
28	0	12	6	0	I	V	26	2-1

SB	NVF
1	1
2	1
3	1
4	1
5	1
6	1

SB	VFN LIST...
1	23
2	24
3	25
4	26
5	27
6	28

Table D.3. GEO File Generated for Example Grid

SBN	BBN	BI	BID	BIR	TYPE	LAYER
1	7	0.0	0.5	0.0	B	1
2	8	1.0	0.5	1.0	I	1
3	9	1.0	0.5	0.0	I	1
4	10	1.0	0.5	0.0	I	1
5	11	1.0	0.5	0.0	I	1
6	12	0.0	0.5	0.0	I	1
BU		0.0	0.5	0.0	B	1
0		1.0	0.5	0.0	I	1
0		0.0	0.5	0.0	I	1
0		1.0	0.5	0.0	I	1
0		0.0	0.5	0.0	I	1
0		1.0	0.5	0.0	I	1
0		0.0	0.5	0.0	I	1
1		1.0	0.5	0.0	I	1
2		0.0	0.5	0.0	I	1
3		1.0	0.5	0.0	I	1
4		0.0	0.5	0.0	I	1
5		1.0	0.5	0.0	I	1
6		0.0	0.5	0.0	I	1

11111111111111

8111118181118

0.000000000.0
0.100000010.0

5.555555555.5
0.000000000.0

0.000000000.0
0.111101011.0

0.000000000.0
1.001010111

T1 thru T3: Titles. T1 and T2 are optional, T3 is necessary.

SI: Signifies English or SI units. English = 0, SI = 1.

\$L: logical unit numbers used by RMA specific routines.

GO: Used to input the nodes of a GO string (RMA term). Used as a reference line for a renumbering of node identifier numbers done by RMA internally.

GE: Element definitions.

<u>Field</u>	<u>Description</u>
--------------	--------------------

1	The first integer is the element identifier.
---	--

2-9	The next eight integers define the nodal connectivity of the element. The node ordering is counter-clockwise beginning at a corner then sequentially around the perimeter. Eight integers are always used. Triangular elements that have only six nodes will have the remaining two integers set to zero.
-----	---

10	Material identifier (internal to RMA)
----	---------------------------------------

11	A real value. Represents the direction of the eddy viscosity tensor for the element and is usually left as zero.
----	--

GNN: Corner node coordinates.

<u>Field</u>	<u>Description</u>
--------------	--------------------

1	Integer. Node identifier.
---	---------------------------

2	Real. X coordinate.
---	---------------------

3	Real. Y coordinate.
---	---------------------

4	Real. Z coordinate.
---	---------------------

Midside nodes are not listed. They can be calculated from corner nodes.

Information in the second section Table D1 describes the depth dimension of the grid. This section begins with the specification of the following parameters:

NP - Total number of nodes in grid.

NE - Total number of elements in grid.

NPM - Total number of nodes in the surface plane.

NEM - Total number of elements in surface plane.

Next, the number of nodes beneath each surface node, including the surface node, and an integer indicating the numbering of this column of nodes are specified.

NDEP - Total number of nodes in a column. A column exists for each node in the surface plane.

NREF - Nodes in the surface plane are numbered sequentially. However, all other nodes are numbered in sequential order from the node beneath the surface node to the bottom within a node column. This integer is the starting node identifier for the first node beneath the surface plane node in a node column plus 1.

The final section of Table D1 indicates for each node within a node column whether it is internal to the grid or positioned on the boundary. The following definitions apply.

NSURF: An integer associated with each node column indicating the type of node column. Possible values are as follows:

0 - Internal node column.

1000 - Wall boundary exists at this node column.

1200 - Head boundary exists at this node column.

31000 - M2 tidal boundary exists at this node column.

MAPPER Output Files Descriptions

The program MAPPER.C reads the node-element connectivity file and generates the output files MAP and GEO files used as input by ICM. When MAPPER reads the node-element connectivity file, it builds an internal RMA grid. MAPPER is aware of how RMA numbers its nodes and elements. After completing the internal RMA grid, MAPPER can then write out the linkage and geometry data ICM needs. MAPPER will create the MAP and GEO files. The MAP file contains the RMA element to ICM cell correspondence and flow face definitions. The GEO file specifies the vertical relationship between ICM cells and lists the QUICKEST weighting distances.

ICM MAP File Description

The MAP file contains four sections of data. A brief explanation of each section follows below.

The first section lists the correspondence between ICM cell identifiers and RMA element identifiers. Note that the two models have different numbering schemes for their cells. This section establishes the relationship between the two numbering schemes. The FEMCONVT.F program, which reads the RMA binary output file, writes out data in terms of RMA internal element numbers and node numbers; therefore, the information in this section will allow a unique identification of each cell and flow face.

RMA numbers elements sequentially in the order of their creation for the surface layer. Next, it numbers its elements from the bottom up to the layer beneath the surface layer going from one column to the next in the order of the element numbering in the surface layer. The ICM numbering scheme sequentially numbers the cells within a layer starting with the surface layer then progressing to the layer beneath till the last layer has been processed. Definitions of the parameters for this section follow.

ICM - Unique ICM cell identifier.

FEM - Unique RMA cell identifier corresponding to the appropriate ICM cell.

The second section identifies each flow face in the grid. Definitions of the parameters for flow face definition follow.

FFID - Unique flow face identifier.

ILB - QUICKEST far upstream weighting cell identifier.

IB - Cell identifier for flow donor cell.

JB - Cell identifier for flow receiver cell.

JRB - QUICKEST far downstream weighting cell identifier.

TYPE - Character variable indicating type of flow face. B indicates Boundary. I indicates Internal flow face.

ORIENT - Character variable indicating direction orientation. H indicates face is oriented for horizontal flow. V indicates face is oriented for vertical flow.

LAYER - Indicates what layer the flow face is in.

The third section lists the number of vertical flow faces in a cell column beneath each surface cell. Definitions of the parameters for this section follow.

SB - Surface cell (box) identifier.

NVF - Number of vertical flow faces beneath the surface cell.

The fourth section lists the vertical flow face identifiers for each ICM cell column iterated in the third section. Definitions of the parameters necessary for this section follow.

SB - Surface cell (box) identifier.

VFN - List of all flow face identifiers oriented vertically beneath a surface cell.

ICM GEO File Description

The GEO file contains three sections of data. A brief explanation of each section follows below.

The first section identifies for each surface cell the bottom cell directly beneath it. Definitions of the parameters for this section follow.

SB - Surface cell (box) identifier.

BBN - Bottom cell identifier.

The second section identifies for each cell, in increasing order, the cell directly above it. Definition of the parameter for this section follows.

BU - Identifier of cell above. Cell identifier is implicit in line order.

The third section specifies the QUICKEST weighting distances for each flow face. Definitions of the parameters for this section follow.

BI - Centroid to centroid distance between IB cell JB cell.

BID - Distance from centroid of IB cell to flow face.

BIL - Centroid to centroid distance between ILB cell and IB cell.

BIR - Centroid to centroid distance between JB cell and JRB cell.

TYPE - Character variable indicating type of flow face. B indicates Boundary. I indicates Internal flow face.

LAYER - Indicates what layer the flow face is in.

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